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ABSTRACT

Seventeen scientific processes are identified and annotated; some suggestions for activities to demonstrate them are given. These processes are used as headings in the teacher's guide to succeeding units on biological classifications, microbiology, physiology of plants and animals, chick embryology and ecology. Similar headings are usually used in the exercises provided in the student's section, which gives detailed instructions for experimental procedures and has questions to guide analysis of the data. A guide to collecting and culturing fresh water organisms, and keys to amphibians, reptiles, insects, and fishes of Alberta are appended. (AL)

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LIFE SCIENCE
A PROCESS APPROACH

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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SECOND EDITION: REVISED, 1970

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SE 009 888

UNIT I

INTRODUCTION

PREFACE

The Life Science committee has attempted, this year, to provide the Science teachers with a complete core program for the grade seven level. We have tried to cover the conceptual framework as outlined by the Department of Education. As a result of this year's labors we have produced six (6) units:

(I) Introduction to the Scientific Processes
and an Introduction to Living Things

(II) Classification

(III) Microbiology

(IV) Life Processes

(V) Embryology

(VI) Ecology

In addition to the units above, two sets of supplementary material are also included: The Sourcebook for the Biological Sciences (produced by the 1969 Life Science committee) and A Collection of Keys.

Because we wanted to present teachers with a complete years work, much time was spent in writing the students sections. As a result the teacher's sections for these units are a bit on the "sketchy" side.

It is our hope, however, that the materials in this unit will enable the Life Science teacher to provide the students in grade seven with a meaningful and interesting program.

Thanks are in order to the members of this committee who gave so much of their time, so that this program could be produced.

W. Phare

USE OF THE PROGRAM

The material presented here will be more than enough to provide teachers with a total program. By judicious selection the teacher can select those investigations that are most meaningful to his situation.

It should be pointed out at this time that the material presented in the six units is not binding and that the teacher should feel free to revise and delete as he sees fit.

A suggested sequence for the units could be as follows:

UNIT		Time	Month(s)
I.	Introduction	1 Month	September
II.	Classification	1 Month	October
III.	Microbiology	2 Months	November-December
IV.	Life Processes	3 Months	January-March
V.	Embryology	2 Months	April-May
VI.	Ecology	1 Month	June

It should be noted that this sequence is only suggested and NOT BINDING. The teacher should revise it to meet his individual needs.

Each unit is written with a teacher's section at the beginning, followed by a student's section. The notes in the teacher's sections are related to the investigations in the student's section.

The two sections may be identified by the number of the pages. For example the Teacher's Notes are numbered T-1, T-2, T-3, etc., while the Student's Notes are numbered S-1, S-2, S-3, etc.

TEACHER'S NOTES

PART A: INTRODUCTION TO THE SCIENTIFIC PROCESSES

Before a scientist can study Biology or any other branch of science he must be well versed in the Scientific Processes. There are seventeen processes but they do not necessarily come in an orderly fashion because some processes tend to overlap in certain areas.

At this introductory level we will be trying to familiarize teachers as well as students with some of the more difficult processes by using simple activities to help break down the steps or terminology used in the processes. Thus this introductory unit is directed to the teacher because he will have to develop his own activities or fill in the areas where examples are not given.

One thing that you will notice as you move through each process is that there are very few activities dealing with life science. At this level it seems necessary to use inanimate objects because of the ease with which the students can manipulate them. With live specimens they move too fast and some of the processes are lost at the introductory level.

As the class begins to think more scientifically and begins to use the processes in their conversation, begin making up more simple activities using animals in the classroom. This section has a lot of shortcomings but it should help the teacher and his students to think more about the scientific processes by using simple but adequate activities to develop each major area.

Below is an Inventory of Processes in Scientific Inquiry prepared by the Edmonton Junior High School Project group.

A. General Processes

The following are common to all the processes in scientific inquiry listed below, and are observed behaviorally (operationally) as these processes:

1. Communication: all of the basic communication skills (reading, writing, speaking, listening, etc.)
2. Reflective, logical thought: analysis, synthesis, deduction, induction, etc.
3. Evaluative, critical thought: checking reliability and validity, identifying inconsistencies and errors, etc.
4. Creativity: inspiration, intuition, imagination, innovation, thinking, originality, etc.

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[1] Developed from units by Ainsley Sankeralli and Al Merrick

INVENTORY OF PROCESSES OF SCIENTIFIC INQUIRY

1. PREPARATION

1. Identifying and Formulating of Problems
2. Seeking Background Information
3. Predicting
4. Hypothesizing
5. Designing an Experiment

11. EXPERIMENTATION

6. Procedure
7. Observations

III. PROCESSING OF DATA

8. Organizing Data
9. Graphing
10. Treating Data Mathematically

IV. CONCEPTUALIZATION OF DATA

11. Interpretations (inferences)
12. Making and Using Operational Definitions
13. Deriving Mathematical Relationships
14. Building "Mental Models"

V. OPEN-ENDEDNESS

15. Further Evidence
16. Identifying New Problems for Investigation
17. Applying Discovered Knowledge

THE SCIENTIFIC PROCESSES

I. PREPARATION

This major division includes activities encountered before the collection of data begins.

1. Problem
   There are many things and events in the universe about which every person wonders and speculates. Thus, accidently or deliberately we are continually identifying problems, any one of which could be investigated to obtain an answer or a solution.

   To the teacher: stimulate students to identify any problem that they themselves would like to find out about and find some plausible answer to.

2. Background Information
   Before any problem can be investigated or solved, or perhaps even before it can be clearly defined, some information is needed. This consists of background theory, knowledge of what other scientists have done on the same (similar) problem, ideas on the apparatus and techniques to use, precautions, etc. The investigator may already have some useful knowledge for solving the problem. Usually, he can get a great amount of information through literature research and other modes of communication.

   To the teacher: if the student was in the process of using a microscope, you could probably direct him to the library and find out more about its invention and the various uses of the microscope.

3. Prediction

   Predictions are based on the fact that the universe operates in a regular manner, and that we expect known phenomena to occur always in the same manner.

   To the teacher: try the activity Case of the Suffocating Candle and try to evaluate it for its effectiveness before presenting it to your students. Refer to pages T-7 to T-13.

4. Hypothesis

   A hypothesis is a possible or tentative explanation for a phenomenon. This may be anything from a simple guess or assumption to an explanation which is highly probable in the light of known observations on facts.

   There has been some difficulty in differentiating between making predictions and/or hypotheses. If, after completing the simple activity regarding prediction you still find the two conflicting, it would be to your advantage to de-emphasize predictions.

5. Design for Collection of Data

The value of planning the method or procedure is to establish a truth only after proper observations have been recorded. First the researcher has to deal with the variables. Usually one variable is tested while the others are held constant.
After the variable has been studied, it then can be controlled and other variables can be tested.
Having made a decision about the variables, the scientist then develops a method of collecting the data including the apparatus needed, steps to be followed, precautions to be taken, and manner in which it can be recorded.
To answer the question "What do we mean when we say: what is a variable? What is a controlled experiment?", complete the controlled experiment on "What Causes Bread to Mold". Refer to pages T-14 to T-15.

II. Collection of Data

This general category includes the activities associated with the actual collection of data, in the field and/or laboratory. In science teaching this phase is commonly referred to as "experimentation" or "laboratory work".

6. Procedure

The scientist starts his collection of data by following the design. He may be fortunate in collecting sufficient data without encountering unforseen obstacles. However, it is more probable that he will have difficulties in getting or building the required equipment, and setting it up. He may have to learn by trial-and-error how to perform the experiment properly.

7. Observations

The scientist develops keen power of observation. He tries to be systematic so that nothing goes unnoticed in his investigation.
As a result he is prepared for the accidental or unexpected events when they occur.
The scientist also takes into account the precision and accuracy of his results. The precision may be high in that everytime he does a given experiment he gets the same results.
Two very simple exercises in observation are to record in point form all the characteristic features of a 50 ml graduated cylinder and then record all the movements of an earthworm.

III. PROCESSING OF DATA

This general category deals with what happens to the data after collection, but before interpretation.

8. Organization of Data

To make data more meaningful, it often has to be rearranged, compared or classified. Sometimes this step is performed before the actual performance of an experiment because the data was recorded in a "rough" manner and needs to be reorganized in a more compact and meaningful way.

9. Geographical Representation

This process involves systematizing the data graphically, in order to obtain "hidden" information and thus facilitate interpretation and make it more complete. Such "hidden" information is found in extrapolations and interpolations. These graphical representations often make possible hypotheses.

In conjunction with the math department follow the activity on How to Describe Location and then complete the graphing exercise on growing mice. Refer to pages T-16 - T-20, T-21, T-22.

10. Mathematical Treatment

Quantitative data is often processed mathematically to make it more meaningful. In the mathematical treatment, often the chance effects of uncontrolled or unidentified variables become evident.

IV. CONCEPTUALIZATION OF DATA

This general category deals with the process of bringing conceptual understanding and order into the facts (observations or data). Here we are concerned with the PRODUCT or CONTENT of a scientific discipline.

11. Interpretation of Data

This operation takes place after all the observations and data are collected. From the information collected one infers (thinks about what plausible answers would help solve the question at hand) and then accepts these answers or sets up another experiment to verify his findings.

Again a simple experiment on how to make inferences or interpretations by following the activity: The Displacement of Water by Air. Refer to pages T-23 - T-26.

12. Operational Definitions

Formulating operational definitions is only indirectly a process in scientific inquiry; it is primarily an aspect of the language of science. Scientists find it useful and convenient to use a word or a brief phrase to identify the operation of an object or an event in nature. Therefore, an operational definition encompasses the minimum description or minimum action needed to identify an object or event. Often more than one definition is possible, the choice depending on suitability.

One question that comes to mind is how do we go about defining what is living and what is non-living? This question is answered in Investigation 1.

13. Mathematical Relationships

Usually, this process is part of the interpretation of data. One can derive quantitative generalizations and provide information which was not apparent from the data.

14. Development of a Theory

Theory building involves fitting and integrating the new knowledge into the theory already existing; or revising this theory to accomodate both the new and old facts.

V. OPEN-ENDEDNESS

Science is always unfinished business. After an investigation has been completed, the investigation raises more questions than what it probably answered. It is this further need to gather more information to support stated generalizations or explanations.

15. Further Evidence

The level of confidence in a generalization or explanation will be low if errors or weaknesses in some stage of the investigation have been spotted. Those which appeared early might be remedied at the data-collecting stage, while those appearing later may require the investigation to be redone.

16. New Problems for Investigation

The new findings may show some of the old principles to be erroneous, or obsolete and in need of revision. Or the new data may help to settle which of two existing theories is more plausible. In any event, a host of new problems stem from gaps, inadequacies, conflicts, and inconsistencies in the theory, and new assumptions and hypotheses may be formulated as a prelude to new investigations.

17. Application of Knowledge

The scientific knowledge gained from an investigation may be applied in a number of ways. Solving other related problems arising out of the open-endedness of the investigation and gaining knowledge in one area so it can be applied and understood in another area.

LEARNING HOW TO MAKE PREDICTIONS

PROBLEM

Case of the suffocating candle.

BACKGROUND INFORMATION

This exercise illustrates the use of the term PREDICTION in the context of a simple experiment. After some data has been collected in an experiment it is frequently reasonable to predict what the results of a future trail will be. In making such a prediction we are reasoning from our past or present experience. The outcome of the event about which we are making a prediction will itself either confirm or deny that prediction. However, the outcome of an event may confirm a prediction accidentally, so that scientists repeat their experiments to help insure against this possibility. While identical results can be obtained accidentally, the probability of such an occurence is very low.

When different results are obtained upon repetition of an experiment the results themselves may cause us to infer that all conditions affecting the results of the experiment were not the same. It then becomes necessary to evaluate the conditions affecting the results of an experiment to determine whether all were the same or whether some were different, or whether some significant condition has been overlooked. In this way the nature and importance of experimental error is emphasized.

A prediction which is not borne out by experiment can be valuable also and should not be dismissed too quickly. It can be useful to explore the basis for such a prediction. A scientist may have been simply guessing, or he may have emphasized one piece of his observational evidence at the expense of some other important parts of the evidence available to him, or he may simply have made a mistake in his analysis of the evidence. Such a prediction can also be the basis for becoming aware of the need for new observational evidence.

In the activities of this exercise the class will first observe a candle which is covered by a glass jar. You will be asked to predict whether the burning candle will remain lighted longer or shorter under a smaller jar. On the basis of measurement of both jar volume and burning time you will be asked to make more precise predictions of burning time, and finally to compare the validity of predictions based on interpolation with those based on extrapolation of the data presented in graphical form.

ORIGINATING THE PROBLEM

Procedure: (for each group of four students)

one birthday candle
one booklet of safety matches
five bottle caps with corks removed
four glass jars--one each of a half-pint, pint, quart, gallon
paper towel
glass-marking pencil
one tall narrow pickle jar--about one pint
graph paper
ruler
pencil
clock with second hand

Your science instructor will help your group to begin a discussion about fire and burning. He will place a lighted candle on a desk in view of everyone. From this see if you can answer these questions.

1) What do you need to keep a fire going?
2) Do you need only fuel to get a fire started or to keep it burning?
3) Do some fires burn faster than others?
4) What makes a fire burn faster?
5) How are fires put out?
6) What would happen if you put a jar over the burning candle?
7) How long would the flame last in question 6?
8) To check the time interval what units would you use? What is the most accurate?
9) Why are there variations in the times observed?
10) How do you know when to start the time?
11) How can you tell when the flame is really out?

INSTRUCTIONAL PROCEDURE Activity One

The operations in this exercise should be done in groups of four. Each group should have a table on which a set of four jars of various sizes is placed, together with a candle placed securely in a bottle cap. Each member in each group should have a special task to do during the experiment, such as:

A. One student may be the safety officer who holds the matches, lights the candle when necessary (if regulations do not permit, your teacher may perform this task for you), and watches to see that others do not carelessly get too close to the lighted candle.

B. Another student may be responsible for placing the jar over the lighted candle and ventilating the jar before each trial. A jar may be ventilated readily by stuffing a cloth into it, removing the cloth, and repeating the procedure a few times. Unless the air in the jar is renewed between trials, the burning times may vary considerably. The jar should be placed over the candle quickly and not held above the flame in an inverted position for any length of time.

C. Another student may serve as an observer, noting when the candle is extinguished.

D. Another student serving as timer and recorder watches the clock's second hand, notes the burning time, and records it.

Letter the jars using the glass-marking pencil from the smallest to the largest. Letter them A, B, C, D.

Make measurements of burning time using jar C first. Each group should make two or more measurements of burning time with jar C and record their observations in tabular form.

It is recommended that mean burning times be rounded to the nearest whole number of seconds. The column headed "Group Number" will be helpful when comparisons of results obtained by different groups are being made. Place all your data, using the table form as an example in your notebook.

Group Number	Jar	Predicted Burning Time (sec)	Burning Time (seconds)			Mean Time
			Trial 1	Trial 2	Trial 3	
1	C		32	28	35	32

No entry appears under the heading "Predicted Burning Time" since no prediction has been made at this time. If Jar C should happen to be of a different size in one set of jars than in another, burning times may be quite different and may generate some helpful discussion concerning the relationship between jar volume and burning time. In any case, some variation in burning times will almost certainly be obtained.

If you are concerned when successive trials do not give identical results, it will be helpful if you would discuss the reasons for the variations observed with your group. Your science instructor could make these possible suggestions to help your group, to make the discussion fruitful. Such factors as the time lags between positioning the jar over the burning candle and noting the time, or between the realization that the candle has gone out and noting the time, variations in the length of the candle wick or the size of the pool of liquid wax at the base of the candle flame are all factors which influence the observation of burning time or the actual burning time. The importance of renewing the air in the jars between trials has already been mentioned.

Now predict whether the burning time will be longer or shorter using jar A. Record your predictions BEFORE performing the experiment. After you have determined the burning with jar A in a few successive trials, predict the burning time for jar B. You will probably say that the burning time will be between the times obtained for the two jars already tested. Why do you think this will be true? Could you make more accurate predictions if you knew the volumes or sizes of the jars? Suggest the possible ways of measuring this volume.

Rather than dealing with any specific system of units of measurements, it is recommended that the volume measurement be a relative one in which the smallest jar in each group is used as an arbitrary standard. The relative volumes of the larger jars may be found by counting the number of small jars of water required to fill the larger one. These units may then be entered in the table of data in the appropriate column.

The following table of data contains actual results of a series of experiments. Similar, but not necessarily identical results may be expected from your experiments.

Group Number	Jar	Predicted Burning Time in Seconds	Burning Time (seconds)			Mean Time	Jar Volume
			Trial 1	Trial 2	Trial 3		
1	C	-------------	32	28	35	32	4
1	A	shorter, maybe(8)	8	9	10	9	1
1	B	18, 16, 14, or 20					2
1	D						8

The predictions can now be made with more confidence since it can be seen that the volume of jar B is twice that of jar A, or half that of jar C, and either individual burning times, or mean burning times obtained with these jars, can be the basis for fairly accurate predictions of burning times in jar B.

Activity Two

The data obtained in Activity one should be available for Activity 2. Now predict the burning time of the candle in jar D. If that jar has a volume of eight units (twice that of jar C, the first one used) it is likely that the PREDICTED burning time will be twice that obtained in jar C. Can you think of a way in which the data you have recorded in your tables could be presented to make this prediction more readily and more confidently?

If the suggestion of graphing is not made, your instructor could bring up these possible questions:

1) What variables should be graphed?

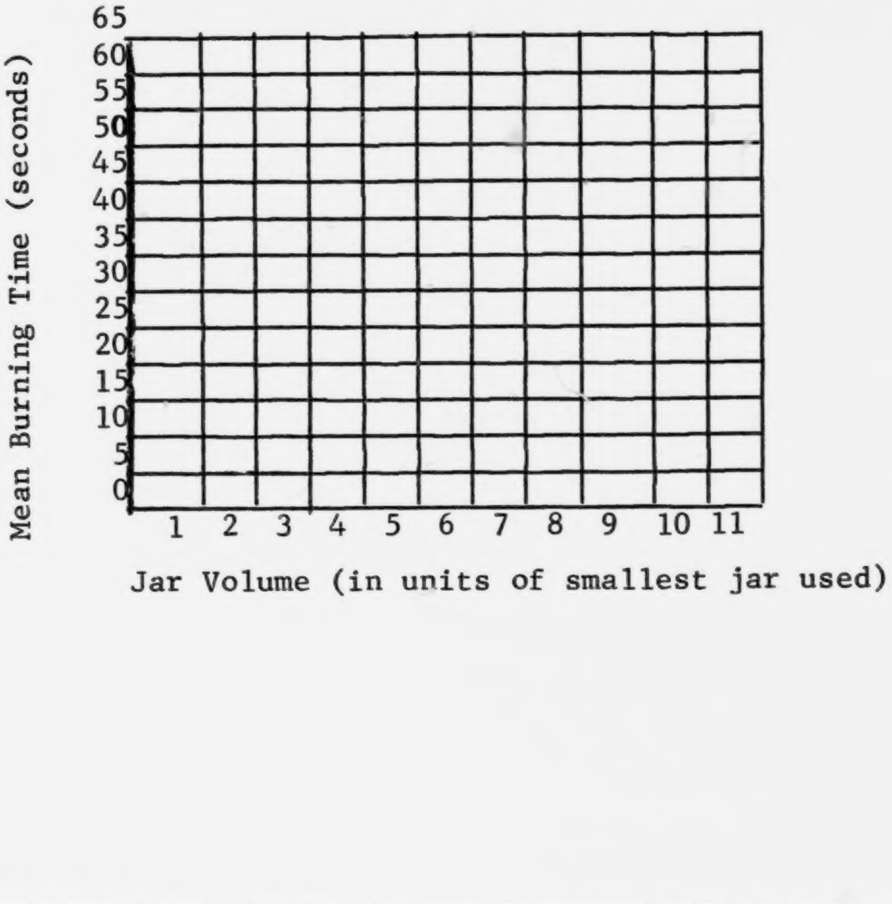
2) What has been measured?

3) What condition was changed?

4) What direction (horizontal or vertical) should be used for each variable?

The table of data should be kept up-to-date by entering items of data immediately after they are obtained. At this point each group should have measured burning times on three different jars.

The corresponding graph might look like this:



Discuss your group's predictions and ask one or two of your members to demonstrate the use of their graph in making a prediction of burning time. When the use of the graphs for the purpose of prediction has been clarified, by laying a ruler or straight edge along the line of points, PREDICT the burning time for the largest jar available. Make your first prediction without the use of your graph, and then make a second prediction using the graph and to compare the two predictions, considering which prediction is more reliable.

This may require an extreme extension of the vertical scale on the graph paper and if so, some difficulty will be encountered. This difficulty can be relieved somewhat by attaching a second piece of paper to the first. This extreme extrapolation emphasizes its uncertainty. Modest extrapolations are more reliable and are commonly used. Why is one prediction more reliable than another?

Now review the meaning of the terms "extrapolation" and "interpolation". Extrapolation involves predicting values BEYOND those actually observed. Interpolation involves predicting values BETWEEN those actually observed. What is the most reliable basis for prediction in terms of your observations?

Discuss the results obtained and then determine how the reliability of an extrapolated prediction changes as one gets farther and farther from the points on the graph which represent actual observations made. Give reasons for your answers.

Generalizing Experience

Other interesting variations on this exercise may be studied such as:

1. the variation in burning time with the position of the jar over the candle. The jar may be systematically elevated by placing it on three wood blocks, placed symmetrically about the candle. Set the blocks of various thickness below the jar.

2. the candle may be moved symmetrically from the central location within mouth of the jar toward a final position against the rim of the jar. More distant positions of the candle with respect to the jar rim can be recognized if a wide mouth jar, such as a peanut butter jar, is used.

3. the height of the candle in the jar can be varied by placing the candle on one or more blocks.

4. various types and sizes of candles may be used.

5. the variation in burning time with a set of jars may be studied without intentionally renewing the air in each jar after each trial.

Appraisal

With your long pickle jar, try to predict the burning time of this odd-shaped jar. How would your group go about this task?

A CONTROLLED EXPERIMENT

To illustrate a controlled experiment and to gain experience in making direct observations, let's ask questions and proceed to answer them as a scientist might. There is no single experiment that would answer these questions but we will limit ourselves to this question, "What causes bread to mold?" To learn the answer we have to ask many questions. Since bread often molds in the conditions that exist where we store it in our homes, we need to consider each of these conditions separately, and from the answers we get to individual questions, decide what conditions seem to contribute to the growth of the mold in bread. Such questions might be:

1. Does the temperature affect the growth of mold on the bread?
2. Does the amount of moisture present affect the growth of mold on bread?
3. Does the amount of light present affect the the growth of mold on bread?
4. Does the growth of mold on bread depend on time?
5. Does bread mold develop and grow as readily on the crust as on the face of a slice of bread?
6. Do homemade baked goods seem to mold as readily as those produced by commercial bakeries?

In each of these questions, there are only two possible answers. With a carefully designed experiment we can probably conclude whether any one question may be answered yes or no. But we cannot, with one experiment, possibly answer the above six questions. In addition, we need to word our questions in such a way that we believe we know the answer already. Let's choose one question from the list given in the preceding paragraph.

QUESTION

Does the amount of moisture present affect the growth of mold on bread? (The skill we exercise in presenting the question greatly affects the quality of the answer we receive).

HYPOTHESIS

(Your best possible guess). Whether we choose yes or no as your best answer should depend on your previous experience.
Can you recall, as you have observed bread mold in the past, the conditions present that might have some influence?

ATTACK

Here is a suggestion of procedure to produce some reliable results which will help us conclude whether the answer is yes or no. To carry out this procedure you will need two pieces or slices of bread, two widemouth, airtight jars, two labels or a marking pencil, and some water.

1. Moisten one slice of bread with water and put in in a jar. Screw on the lid to keep the bread from drying out. Label this jar (moist bread) and write the date on the jar.
2. Put the second slice of bread in the other jar. Screw on the lid and label the jar (unmoistened bread). Write the date on the jar.
3. Examine the bread in both jars each day and keep a record of your observations.

RESULTS

On the basis of what you have observed, does it appear that moisture affects the growth of mold on bread?

T - 14

LEARNING HOW TO COMMUNICATE

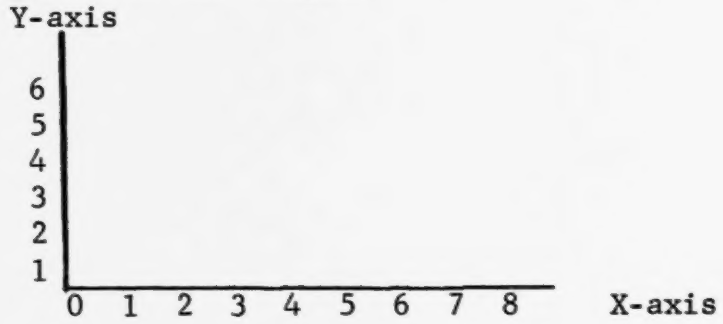
PROBLEM

How to describe location.

BACKGROUND INFORMATION

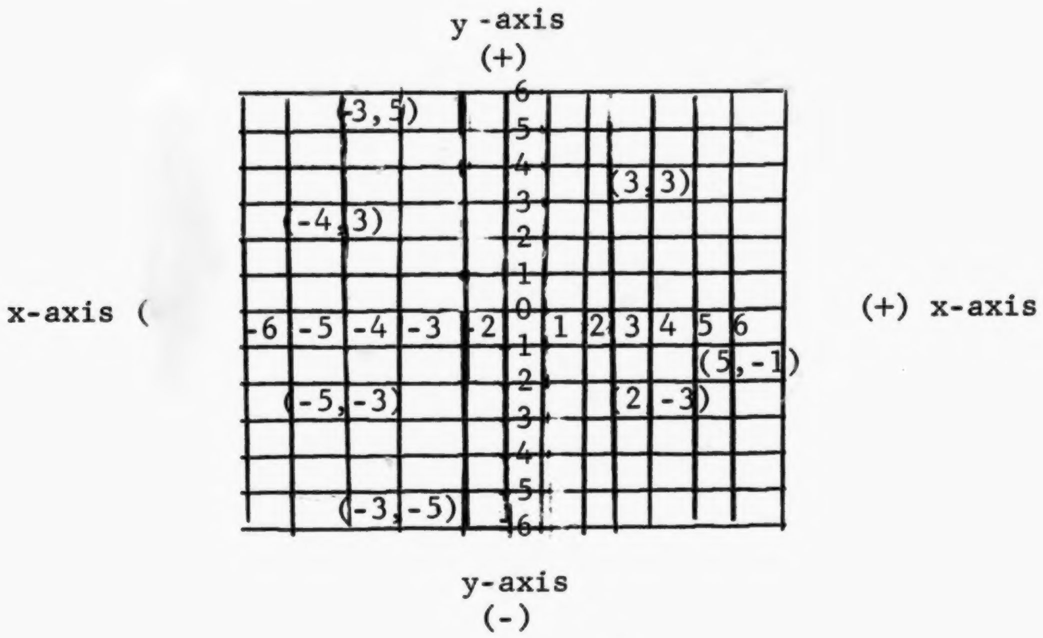
In technology and science it is often necessary to describe with precision the location of points, lines, planes or objects. The establishment of a reference system is essential for this purpose. One of the most widely used grid systems is the Cartesian or rectangular coordinate system. The simplest notions of such coordinate systems have already been used in the previous exercise. This set of activities will introduce you to a more formal idea of the sustem and its uses and will give you an opportunity to locate points on the graph.

It may be helpful to review Cartesian coordinate terminology although some of the terms need not be explained at this time. There are two axes at right angles to each other usually represented as horizontal and vertical, although not necessarily so. The horizontal axis is usually called the x- axis and the vertical axis is called the y-axis. They meet in a point called the origin. Any convenient scale may be marked on the axis, starting with 0 at the origin.



The position of a point may be determined by drawing one line through it parallel to the X-axis and another parallel to the Y-axis. The line parallel to the X-axis meets the Y-axis. The number on the Y-axis scale at which the line meets the Y-axis is called the Y-coordinate of the point. The line parallel to the Y-axis meets the X-axis. The number on the X-axis scale at which the line meets the X-axis is called the X-coordinate of the point. The two together are referred to as the coordinates of the point and are written in parentheses as (x, y), the coordinate always being written first. The coordinates of a point are often referred to as an ordered pair because the order in which the numbers are written is significant.

Coordinates may also be expressed as negative numbers. The coordinate axes x, y extend beyond zero and include the negative side of the number line. To the right of the Y-axis the X-coordinate of a position is negative. Above the X-axis the coordinate is positive, while below the X-axis the Y-coordinate is negative. A rectangular coordinate usually has the orientation of the next diagram, but again not necessarily so.



PROCEDURE

1. Graph paper with large squares (blocked paper)
2. Two colored pencils--possibly one red and the other blue (per person)

From the class your science instructor will collect data from each person about the month of each person's birthday. To get things started this record will be marked on the blackboard.

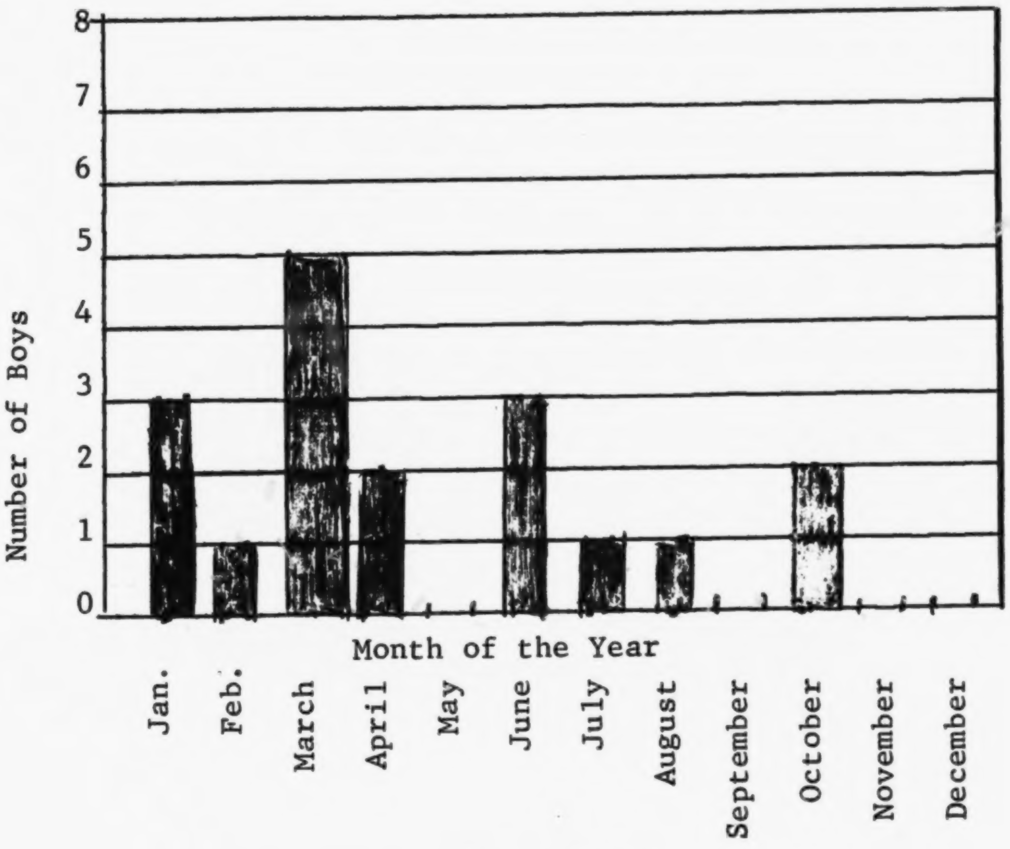
	Boys	Girls
January Birthdays	3	2
February Birthdays	none	1
etc.		

Write the names of the months along the horizontal axis and the number of students along the vertical axis. Then graph the information relevant to the boys. The graph should be in the familiar form of a bar graph.

1) In which month do most boys have birthdays?
2) How many boys have birthdays in the summer?

Now graph the girls' birthdays on the same graph. This should give us the complete information at one glance.

3) How can you plot the girls' birthdays if the boys' birthdays are already on the graph? Explain your method of plotting this data.
4) Is there another method of graphing that will help to eliminate the problem encountered in drawing this graph?

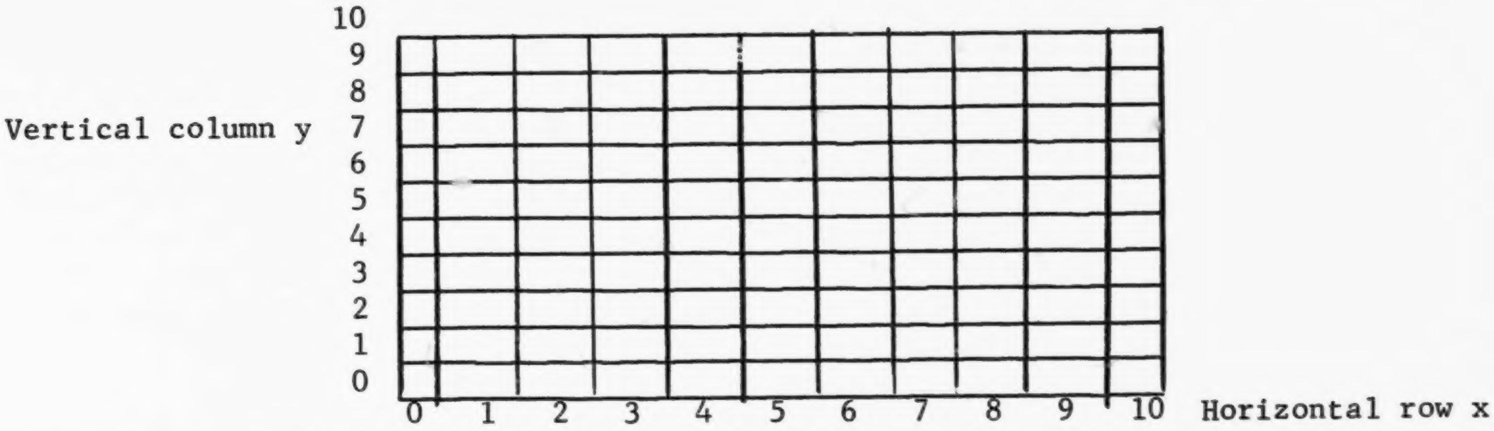


Activity One

Draw a grid on a blank piece of paper. It should be large enough for easy workability and have enough rows to be labeled 0 to 10 in both vertical and horizontal rows.

For our convenience in this exercise we will number all the rows going across "x" and all the rows going up "y".

Place a point at the intersection of two lines, perhaps the intersection of the second x-row and the fourth column. Describe the exact location of this point. The graph should be numbered in the following manner



Use two numbers to describe the exact location of the point. Now try to locate these numbers on your graph, (7,4), (6,3), (1,5). Remember this notation is used to write an ordered pair. Where is the "x" number, the "y" number?

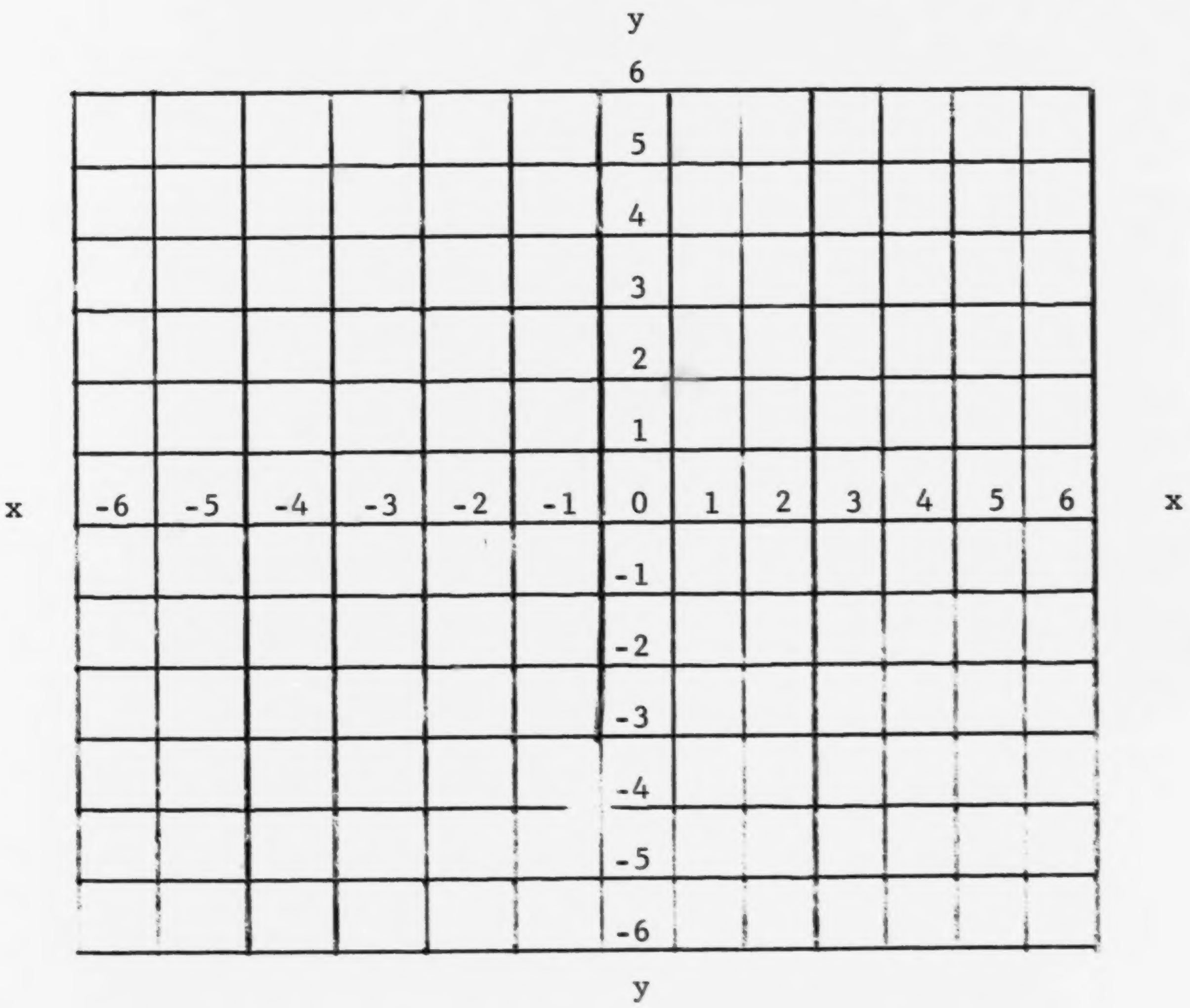
Activity Two

With a new sheet of graph paper, plot the birthday data with a point instead of coloring in a bar. You should take your blue pencil and consider what point on the graph would indicate what boys had birthdays in January. Using your fingers trace the vertical line that indicates January and then trace the horizontal line that indicates the number of boys. At the location where one line crosses the other line mark a blue point. Continue with all the boys' birthdays until that information has been graphed.

The girls' birthdays should be graphed in a similar manner but use your red marking pencil.

1) Does this new type of graphing help to eliminate the problem encountered with the bar graph?

2) Can you find exact locations of points without grid lines? What is needed now?



3) How many parts does the new graph include?

4) How would you locate the point (2,4)?

5) How would you locate the point (-2,4)?

6) Plot these points: (3,1), (-6,2), (-4,3), (5,-2), (4,5), (0,4), (-2,-6), (2,-4).

GRAPHING EXERCISE

The weight of young male mice was measured and recorded for a period of four weeks. The data obtained was as follows:

Age in Days	Average Weight in Grams
20	4
27	13
34	17
41	20
48	21

Draw the graph of the results in the space provided. Follow these instructions before plotting your points.

1) Mark the horizontal axis off into units of five.

2) Mark the vertical axis off into units of five.

3) Decide which is the DEPENDENT variable and the INDEPENDENT variable, and then place it on the correct axis.

4) Plot the points on the graph from the chart.

5) Join the points with a pencil.

QUESTIONS: ANSWER THESE QUESTIONS ON THIS PAGE

1. Did the mice increase in weight faster at any time during the period of growth? Explain.

2. Were they still increasing in weight at the time the four weeks had passed?

3. Estimate from the graph how much they would weigh at 22 days, 37 days, 45 days, and 55 days.

LEARNING HOW TO MAKE INFERENCES

PROBLEM

The displacement of water by air.

BACKGROUND INFORMATION

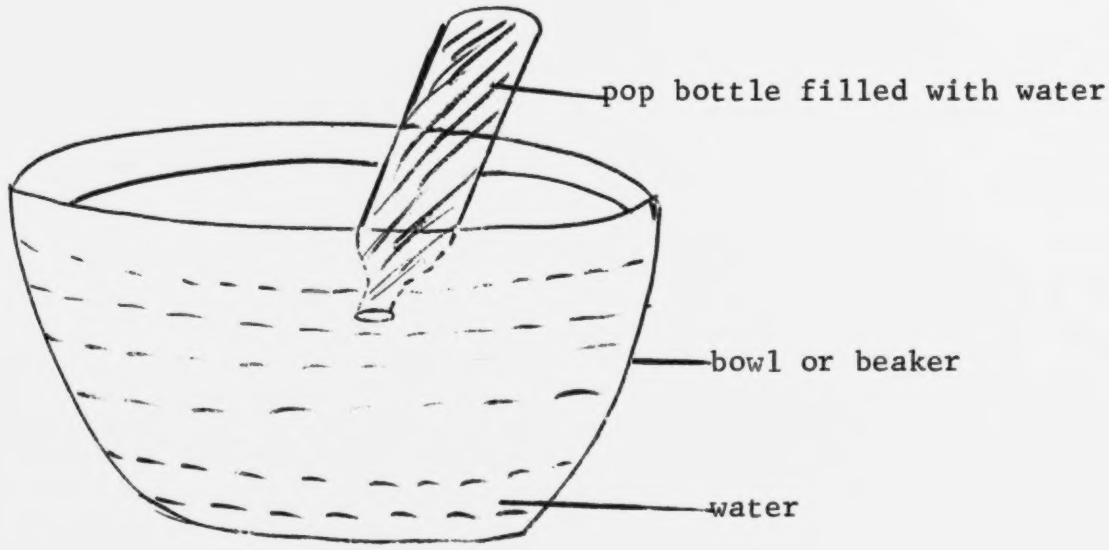
This exercise will give further experience in making inferences. Here we will learn how to make inferences from observations of less familiar phenomenon, and then we will test these inferences. In this exercise you may feel very certain that the water was pushed out of the bottle by the air but it is doubtful whether you will be able to state this clearly by recording it in your own words.

Every inference made, no matter how unreasonable it may seem, should be subjected to the same careful, dignified analysis. Some make better inferences than other students because they make more observations, keep the observations more clearly in mind, or process a richer store of prior knowledge upon which to draw. This should be an advantage, since the objectives of this exercise will be attained more fully if you have an opportunity to compare inferences of varying quality.

PROCEDURE

one bowl, dishpan, or beaker of about 2 liters capacity for each group
one soft drink bottle (10 oz.) with a stopper or cap
several papers or folds of newspaper
one drinking straw for each person
one kitchen baster or large medicine dropper
food coloring to color water
model clay or wax
one widemouth jar
one package of Alka-Seltzer tablets
equal-arm balance and weights

Set up the equipment for each group of four students.



1. Fill the bowl abot half full of water.
2. Fill the bottle with water and insert the stopper (or cover the mouth of the bottle with a bottle cap, or with a small piece of cardboard).
3. Invert the bottle and place the mouth of the bottle under the surface of the water in the bowl.
4. Remove the stopper or cap. The water will flow from the bottle if the opening remains below the surface of the water in the bowl.
5. Place several drinking straws near the bowl.

How could you get the water out of the bottle without turning the bottle over or pulling it out of the water?

Activity One

OBSERVATIONS

1. Bubbles went up into the bottle.
2. Some bubbles went up outside the bottle.
3. The water level in the bottle went down.

The statement, "The water in the bottle disappears", may require some discussion. It is a statement of observation rather than one of inference.

1. Did the water in the bottle disappear all at once, or did it disappear gradually?
2. Did it disappear while bubbles of air were going up into the bottle, or did it disappear at other times?
3. What happened to the water in the bottle?

Try to clearly distinguish between what you actually saw (observation) and what you think occurred (inference) but did not actually observe.

Activity Two

How would you test the inferences you have made in the exercise?

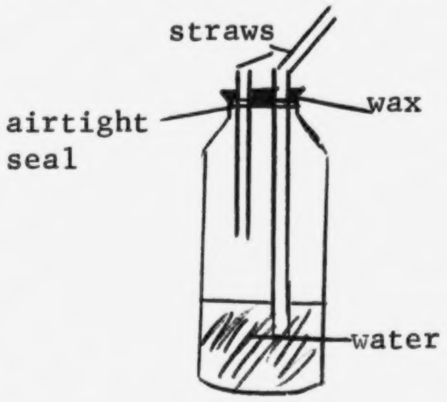
A quite simple way to test the inference that the water flows out of the bottle when the air flows in is to measure the change of the water level by marking the bowl before and after emptying the bottle. The bottle should be kept immersed in the water to the same depth while this is being done. A mark on the bottle at the water line will make it easier to keep track of this. To confirm that the rise in the water level in the bowl is produced by the amount of the water in the bottle, you could check this by emptying the bowl to the first mark and measure the rise in the water level that is obtained by pouring water out of the refilled bottle into the bowl.

To test the inference that water simply disappears, the bowl, bottle, and water can be weighed before and after the water is removed from the bottle by blowing air into it.

The most direct method is to color the water in the bottle but not in the bowl. Then when air is blown into the inverted bottle you will be able to observe the colored water flowing out and mixing with the water in the bowl. How could we make the water in the bottle look different from the water in the bowl? It would probably be best to allow the bottle with the colored water to stay inverted in the bowl a few minutes before blowing up into the bottle.

Generalizing Experience

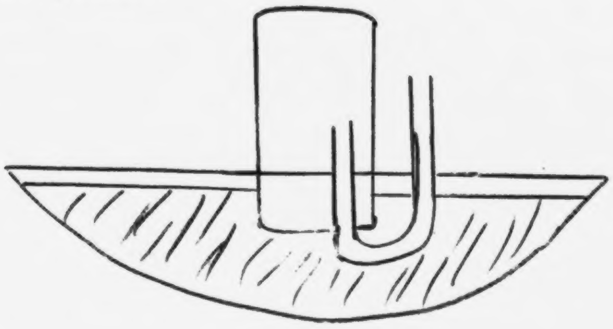
1. Arrange a bottle partially full of water as shown in the diagram. Cut a top of cardboard and make two holes in it for drinking straws. Seal the top and the space around the straws with masking tape or wax so that the only way liquid or air can enter the bottle is through the two straws. One straw should extend only into the air space in the bottle, the other should extend well into the water.



When one blows into the short straw the increased pressure in the bottle forces water out the long one. Discuss your observations and inferences as to what happened. Here the inference is an explanation of the question, "Why does the water spurt out of the straw?"

2. Using the same equipment as used in Activity 1, empty your bottles and place them next to the bowls of water. How can you use a straw to carry water from the bowl without losing the water from the straw?

3. Invert a glass and push it down into a bowl of water. Observe that the water is not in the glass. How can we get water into the glass? Must we let the air out? A bent straw or tube can be used to let the air out of the glass.



Appraisal

Fill a clear glass, with a wide mouth bottle about half full of colored water. Insert the baster or large medicine dropper about halfway into the water. Watch carefully what happens. Slowly squeeze the bulb and release it. Think about what you observed and what you could infer about what happened. Empty the tube and release it. Think about what you observed and what you could infer about what happened. Empty the tube and repeat the process.

WRITE OUT SEPARATELY YOUR OBSERVATIONS AND YOUR INFERENCES BY DIVIDING A PAGE IN YOUR NOTEBOOK AND THEN COMPARE THEM.

If there seems to be sufficient interest this could be repeated with the bulb squeezed while the end of the tubing is out of the water. Next put the tubing into the water and release the bulb. If this is done well it should not look noticeably different from the preceding situation except that there will be no bubbles. It could be a good test for you in making careful observations. What is the difference between making observations and inferences?

PART B: INTRODUCTION TO LIVING THINGS

--This section serves the following purposes:

1. To give pupils an idea of the importance of Biology in daily life.

2. To give pupils an overview of what they will be doing for the rest of the year.

3. To give pupils an understanding of the nature of living things.

- Teachers may wish to have pupils amplify what is being done in this section by having them do some literature research on the following topics:

  1. Famous Men in Biology
  2. Famous Discoveries in Biology

- At the start of the school year have the pupils make collections of plants and animals. Many of these can be obtained from sloughs, lakes, ponds, etc. In collecting pond water, have the pupils include some of the surface scum and mud from the bottom.

- The eight activities described are intended to represent all of the units which will be done in detail later on. The idea here is to have pupils make as many and as detailed observations as possible. From these observations they can hypothesize explanations and test them later on.

- Some of the observations to be made on the activities are as follows:

Activity 1		
variety of life plants and animals	classification	
movement breathing securing food	life processes	interdependence

Activity 2		
movement eating excretion breathing	life processes,	responsiveness

Activity 3
cellular structure of living things

Activity 4
growth
reaction to environment

Activity 5
osmosis
how food is taken in by cells

Activity 6
how life is propagated

Activity 7
photosynthesis use the glowing splinter test for oxygen

Activity 8
photosynthesis
interdependence of living things

NOTE:
brom thymol blue solution is yellow in excess CO_2 and blue in the absence of CO_2. During the day it is blue. In a dark place it is yellow because plants cannot use up the CO_2 in the dark.

- Have pupils summarize their observations under headings that will point out the characteristics of living things:

  growth
  reproduction
  responsiveness
  adaptation
  metabolism

- Definitions

metabolism
the sum of the life sustaining processes which provide for the maintenance, growth and repair of the living organism
metabolic activities include respiration, digestion, assimilation and excretion.

respiration
the chemical break-down of food with release of energy

digestion
is the transformation of complex into simple foods

assimilation
is the conversion of non-living chemical compounds to living matter

excretion
is the release of the waste products of metabolism

Without metabolism the other life functions would not continue.

ANSWERS TO QUESTIONS

1. building blocks called cells

2. yes, seeds will not germinate if conditions are not right

3. by carrying on the processes listed in the definitions

4. living things adapt (hibernate, migrate) or die

5. yes, because of the great variety of life and the similarities among some, you can put them into groups with similar characteristics.

6. living things coming from non-living things

7. so as not to allow any air in. You then have a closed ecological system showing interdependence between two living things

8. cheesecloth

9. corn syrup - protoplasm (cell fluid)

   water - substance around cells (liquid bringing in broken down food)

10. to maintain the oxygen carbon dioxide cycle. They are producers of food

11. the fish would die unless oxygen can be dissolved in the water

STUDENT'S NOTES

INTRODUCTION TO THE SCIENTIFIC PROCESSES

Biology is the study of Living Things. Curiosity and enjoyment have been and still are, to a certain extent, the basis for studying Biology and indeed most branches of science. Today, however, we know that the study of Biology is necessary for the survival of modern civilization. Through this study we have been able to establish the causes of certain diseases and to devise methods of controlling them. We hear about the population explosion and the resultant famines which have struck many underdeveloped countries. Scientists have brought some relief by developing new strains of animals and plants which are more productive and hardier. These are but two examples of how the study of Biology has helped us.

While most of you may not enter the field of Biology, the study of this subject will make you better equipped to deal with situations that you will face in a few years--discussing and voting intelligently on such issues as fluoridation, drugs and pollution.

Lastly we must remember than man himself is a living thing and that by the study of Biology he develops a better understanding of himself.

In the previous section you studied some of the PROCESSES of science. The following section allows you to apply these processes to the World of Living Things.

Investigation 1

PREPARATION

Problem
Is a candle flame living or non-living?

Background Information
In your research attempt to determine what
a) living is
b) non-living is
Having determined the meaning of these two terms attempt to identify the processes that would make a burning candle a living or non-living thing.

Hypothesis
From your background information formulate a hypothesis as to whether the candle flame is living or non-living.

Design for Collection of Data
Light a candle and let it burn for 30 seconds. Drip the molten paraffin in the middle of a pan or dish. There should be a sufficient amount of hot liquid wax in the pan to secure the candle in an up-right position.

COLLECTION OF DATA

Procedure
Follow the design and record any changes in and additions to the design.

Observations
Draw a diagram of the candle and the flame. Observe the flame for two minutes and record your observations.

Interpretation of Data
Answer the following questions. Compare these questions to some suggested plant or animal found in Alberta. How do they compare?

1. Does the flame need air?
2. Does the flame need oxygen?
3. Can you smother the flame?
4. Is the flame warm?
5. Does the flame move?
6. Does the flame grow?
7. Can the flame reproduce?
8. Does the flame give off wastes?
9. Does the flame need fuel?
10. Is the flame sensitive?

OPEN-ENDEDNESS

New Problems
1. What methods or techniques could we use to determine if something is living or non-living?
2. Can we be sure of stating that the candle flame is non-living by backing up our statement with proof?

Application of Knowledge
How can we limit our search to identify the basic structural units of which living matter is composed?

Investigation 2

PREPARATION

Problem

What are the characteristics of Living Things?

Background Information

The following questions may be of use in solving the problem:

1. What is life?
2. Where does life come from?
3. How do you know that something is alive or that it once lived?
4. How is life maintained?
5. How does life continue from one generation to another?

You will need:

1. pond water
2. plant collections
3. animal collections (including pets)

These should be secured and set up in the classroom as early as possible. Your teacher will explain how to secure them and maintain them in the classroom.

In studying science in previous years you used living things. Try and recall some of the characteristics which living things possess (and which are not possessed by non-living things).

The following activities will help to refresh your memory. You are to choose one of these activities in cooperation with your teacher and carry it out.

Investigation 2 (cont'd)

Procedure and Results

For each activity:

1. carry out the procedure suggested
2. make accurate and detailed observations
3. record observations either by (a) written description
   (b) neat diagrams

Activity A

- Secure a sample of pond water. (Your teacher will tell you how to do this.)
- Use a hand lens to examine it and describe what you see. If possible draw diagrams.
- If you can, transfer some of the small organisms in a drop of water and examine it under a microscope using low power.
- Again describe what you see drawing diagrams where possible.

Activity B

- Bring a pet to school and examine it for a few days.
- Think of some of the things you have to do to maintain it.
- Describe its activities in detail.

Activity C

- Secure some water plants, tender leaves and roots, cheek cells
- If you have not already done it, ask your teacher to show you how to make a temporary slide of the root tip or leaf section or cheek cells
- Examine the slide under a microscope and describe what you see. Draw diagrams.

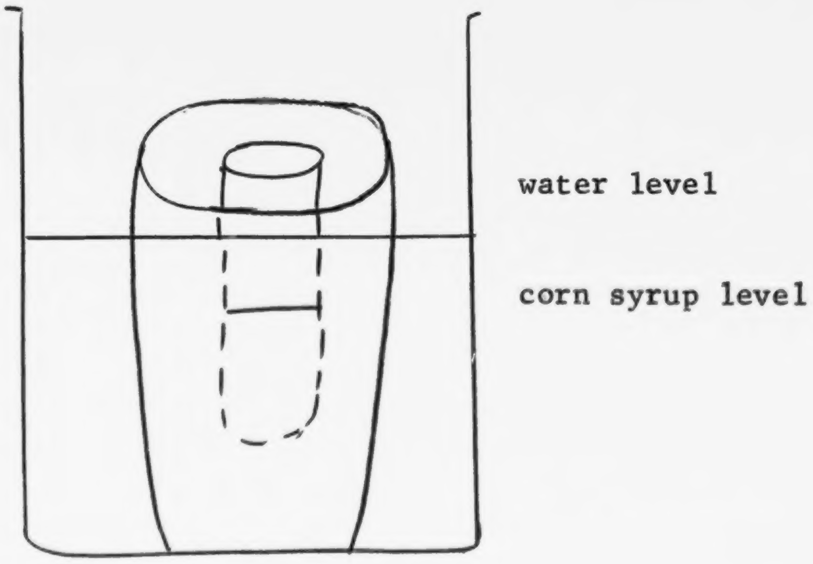
Activity D

- Germinate a few bean seeds.
- When the seedlings are growing, take one and put it in a completely dark place. Supply it with food and water (keeping it away from light at all times).
- Describe what happens.
- Take another and supply it with everything except water.
- Describe what happens
- Take another and supply it with everything except air. To do this keep the roots flooded with water at all times.
- Take another and supply it with everything. Keep it in a cold place. Describe what happens.

Investigation 2 (cont'd)

Activity E

- Take half of a large potato and make a hole in the centre (see diagram). Cut a slice off the bottom.
- Place enough corn syrup to fill the hole halfway.
- Note the level.
- Place the potato and syrup in a beaker and fill the beaker to the point where the water level is about three quarters up the potato. Note the level.
- Leave overnight and observe next day or two.



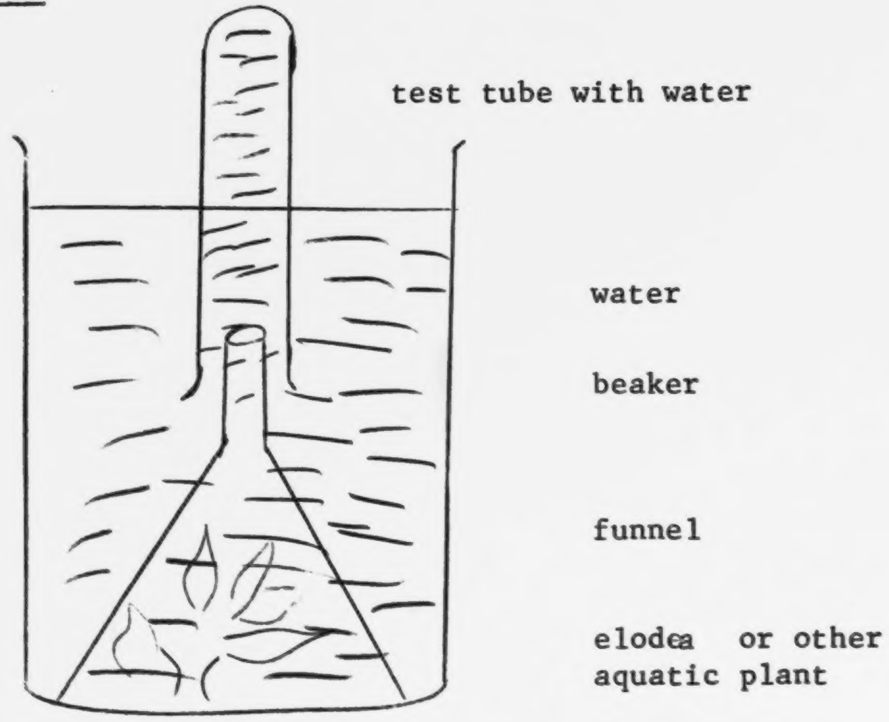
Activity F

- Take three jars and place a piece of raw meat in each.
  Jar A - leave uncovered
  Jar B - cover with a cheesecloth
  Jar C - seal tightly

- Leave the three jars in an open place where there are flies.
- Observe over a period of several days.
- Record observations.

Investigation 2 (cont'd)

Activity G



- See diagram above.
- Fill a large beaker with water and place the plant in the center.
- Cover the plants with a funnel. The top of the funnel should be below the water level in the beaker.
- Fill the test tube completely with water and place it over the funnel opening.
- Secure the funnel with a clamp.
- Leave in a sunny place for a day or two and describe what happened.
- Test any gas collected for oxygen.

Activity H

- Take two test tubes.
  In A - place some aquarium water and one snail.
  In B - place some aquarium water and one snail along with some green aquarium plant.
- In each test tube place some brom thymol blue solution that has been turned yellow by breathing through it with a straw.
- Seal test tubes air tight with rubber stoppers.
- Place test tubes in light (not direct sunlight).
- During the night leave them in a completely dark place.
- Observe any color changes that take place.

Investigation 2 (cont'd)

Interpretation of Data

- The results of the eight acitivities will be taken up in class.
- After a class discussion you should be able to summarize your findings under a few main categories - what functions are performed by all living things.
- These categories will be the answers to your problem.

Operational Definition

- Give a definition of "Living Things".
- Can you give answers to the five questions asked under PROBLEM.

QUESTIONS

1. What do living things seem to be made of?
2. Are living things sensitive to what happens in their surroundings? Give examples.
3. How is life maintained?
4. What do you think happens to pond life during winter?
5. Is there a basis for classifying things according to your observations?
6. What is spontaneous generation?
7. Why should the tubes be air tight in Activity 8?
8. What is the experimental variable in Activity 6?
9. In Activity 5, what could the corn syrup and water be compared with in a living organism?
10. Why are green plants necessary in a balanced biological community?
11. What would happen if all the green plants in an aquarium should die out?

GOING FURTHER

The work that you have just completed gives you a brief introduction to living things. During the rest of the year you will study each of these characteristics in much greater detail.

You have made many observations and undoubtedly several questions (problems) have arisen. Your next step should be to hypothesize answers to those problems. You should test those hypotheses during detaild study of the units to follow.

UNIT II

CLASSIFICATION

CLASSIFICATION

Investigation 1 - Living Organisms can be Classified

CONCEPTS

1. Variation of Living Things:

    a. Living things may be sorted into groups - classifying
    b. There are many different kinds of living things (this aspect will be developed in the "Background Information).

2. The need for Classifying Organisms:

    a. to organize knowledge
    b. to save time
    c. to identify things accurately
    d. to use a common system

    The teacher should consider exercises that would help the students develop insight into the needs mentioned above.

3. A wide variety of living things may be sorted into large groups:

    a. using more obvious differences of general size, shape and structure (classifying by structure)
    b. containing organisms with certain features in common. (When groups have been made, look at the common features of structure within each group. Teachers may also consider the similarities of performance of the life functions within the group and compare with the performance of the life functions in other groups.)

4. Features of Classification:

    a. decision making
    b. incompleteness (open-endedness)
    c. limitations
    d. exceptions

Processes Involved

1. Problem

    Discussion of the problem should be the introduction to the "need" for a classification system.

2. Background Information

    a. Students should anticipate some of the problems if there were no systematic method of identifying, naming, or classifying animals.

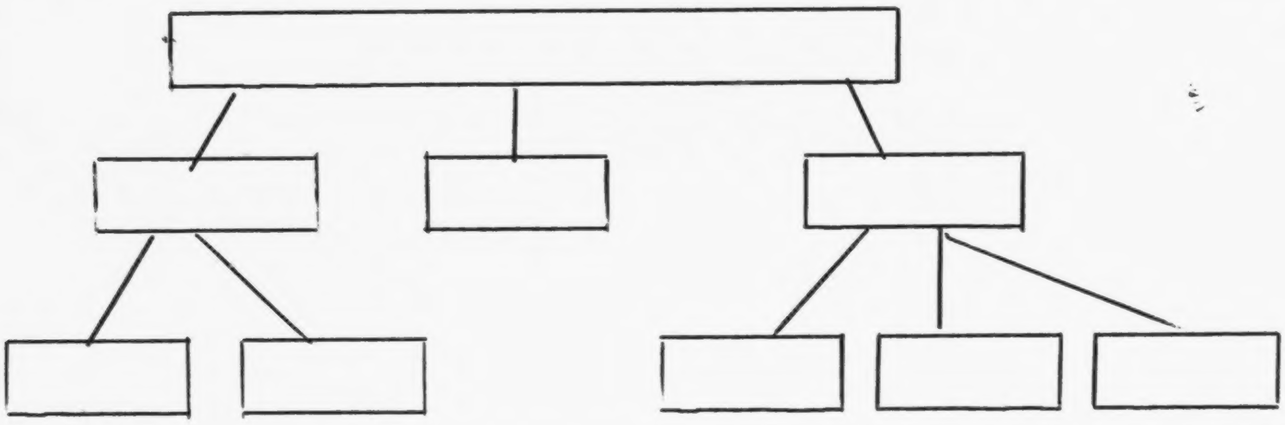
    Example

    1. Puma, cougar, mountain lion, are names for the same animal. Several names can lead to a communications difficulty.
    2. When plotting migratory routes of ducks a common system of naming is essential.
    3. Record other examples that the students develop or that you find useful to illustrate problems that would arise if there were no common classification system.

1. Revised from the unit developed by the 1969 Life Science Committee.

b. Ask students how they might classify a million stamps from every country of the world. Some suggestions may be a division of stamps by color, shape, size or value.

Example:



Students should be made aware that people tend to think in terms of some form of a classification system. For example, when making a list of camping goods for a trip to the mountains the heavy gear may be listed, then the food, then eating utensils and so on. Similarly in the preparation of a grocery list, a person may list the vegetables, the meats, and then fruits that he wishes to purchase.

The chart at the end of Background Information should give the students an idea of the great variety of animal life. Students could be asked to construct a bar graph from the data supplied.

5. Design for Collection and Organization of Data
   The two processes, design and collection, have been combined because in order to design a classification tree the student must also organize the specimens or objects according to their likenesses and differences. An alternate approach to the suggested design is to allow students to examine each of the specimens and list the structural characteristics that they see. The structures of each specimen or object would be recorded as a qualitative observation in a tabular format. From this "Gestalt" or "total picture" the students would be asked to develop a classification scheme for their specimens.

The two exercises at the start of the design are self-explanatory. They may be assigned for homework.

ANSWERS TO QUESTIONS

Exercise I. 1. yellow, solid, 2. brown, square, 3. hard transparent material, 4. coniferous, tall, 5. large, mammals, 6. useful, 7. glass, contains alcohol, 8. blue Ford,
Exercise II. answers will vary

7. Observations

The development of a classification tree involves the use of several processes such as design, procedure, observation and processing of data, as a simultaneous operation or operations that are going on in a rotation of processes.

After students have completed the assignment they may present their classification trees to the class. Stimulate discussion to show the different ways that objects may be classified. Ask students to give reasons for some of their choices. Discuss the pros and cons of some of the decisions they have made.

11. Interpretation of Data

Question 1:

To develop a classification scheme one must:
- identify likenesses and differences of structures
- group on the basis of common structure starting with the more general structures and working towards the more specific structures
- make decisions. For example, is the structure a mature or an immature wing? Is the structure a mandible or a palp?

Question 2:

Some of the advantages of a classification system are:
- saves time
- organizes knowledge
- uses a common system of naming
- makes identification easier

Question 3:

Difficulties & Limitations of a classification scheme may be:
- there are exceptions or uniquenesses amongst animals that make it difficult to place them in a group,
- there are variations within the same group that make it difficult to classify the animal into the same group (e.g. different colors).

Question 4:

Safeway, Library, Department Store.

Allow students to answer the questions before discussing the answers in class.

12. Operational Definition

Classification is the organization of things into groups on the basis of common features.

Enrichment:

Refer to activities as outlined in BSCS Green Version P. 108-113

Application

Before this section is started ask the pupils to collect live specimens and pictures. Pictures should illustrate observable characteristics.

Number all specimens

In (1) the pupils should arrive at the differences between plants and animals.

The characteristics used in (2) may be anything - habitat, usefulness, size, color, etc.

After the tree is constructed pupils should be able to place an unknown specimen in its correct box at the smallest level of classification.

Before starting (7) discuss the fact that there is a universal classification system. Discuss its characteristics and tell the pupils they are going to try and construct one like it.

NOTE For a specific purpose a local less detailed classification may be better.

Charts for observations are the same as those for classification of abstract objects.

Questions

(1) The commonly accepted classification scheme was designed on the selection of structural characteristics other than those selected in the classroom. It is very likely that a more detailed study of the animals has been done by scientists than was done in the classroom. This would enable them to classify by structures that are not easily seen in the classroom laboratory.

(2) Our classification system was developed from a study of about 50 to 60 specimens. The accepted system is more comprehensive. It is useful for all organisms.

The teacher may suggest that the students' system of classification may be superior to the accepted system for the 50 to 60 specimens that they used, but it is limited to those 50 to 60 specimens.

(b) The students should now have a grasp of the principle of classification - organizing on the basis of common characteristics from gross to specific characters.

Stress that since this is a life science course, the previous activities were designed so that the student could eventually classify living organisms.

The handout on "Classification" is meant as an introduction to binomial classification. A more historical approach to the development of the present day classification system may be adopted at the teacher's discretion.

This exercise is largely based on a simplified version of the presently accepted classification of the animals exclusive of the Protozoa. It will probably be helpful to have a number of zoology and biology texts available as additional references for both student and teacher.

In order for the students to classify their specimens it will be necessary for them to be familiar with a certain amount of terminology. This problem can be handled in a number of ways:

1. The teacher can assign a careful reading of the group characterizations and instruct the student to write down all unfamiliar terms, or

2. The teacher can prepare a list of terminology for the student to define. The list should include such terms as bi-lateral symmetry, parasite, anus etc. A useful reference volume of defining these terms is "A Dictionary of Biology" by M. Abercombie, C. T. Hickman and M. L. Johnson - Penquin Books.

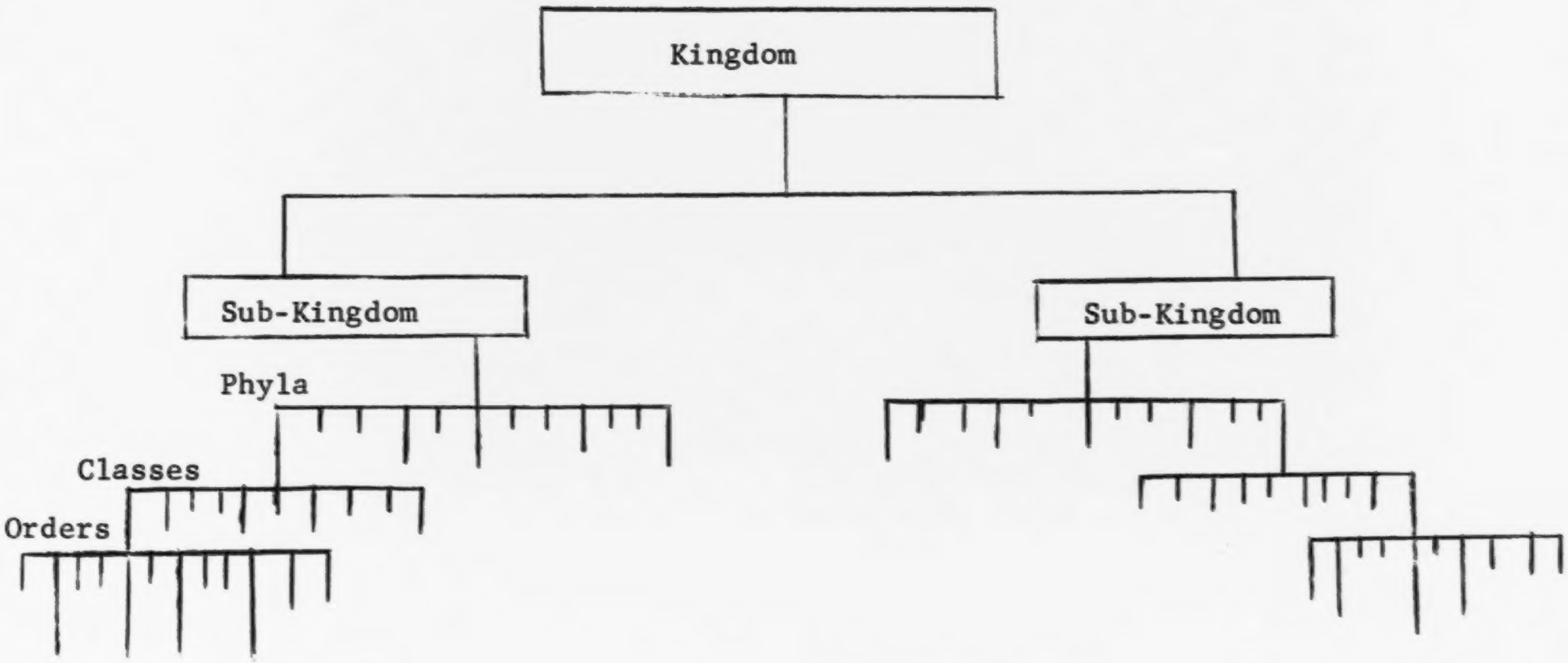
Perceptive students may discover that the grouping employed here is different from that used by other biologists. The differences will mainly involve changes in the taxonomic status of various groups. The sponges, for example, may be given Subkingdom status rather than status as a phylum as done here. The teacher should point out that classification is an ongoing process and that as new knowledge accumulates changes are constantly made. Also, different biologists interpret the data in different ways resulting in slight classification variations. All this in no way changes the usefulness of a comprehensive classification and illustrates that there is nothing absolute about scientific knowledge. Scientific knowledge is always tentative, that is, it is based on available evidence. Where new evidence accumulates our scientific perceptions and formulations also change. This is an important point to get across to young students who often tend to absolutize science.

When the students finish grouping their animals they will still have a number of tasks to complete.

(1) The Class Mammalia will have to be broken down into various orders. Rather than give the characterizations of these orders to the students, it is suggested that they research these themselves in the reference books that are available.

(2) The teacher should go through all the specimens and from a master key read off the numbers of the specimens that go with the different taxonomic groups. Be prepared to engage in some pretty lively debate with dissenting students. There may be a fairly marked confusion of the Coelenterates and the Echinoderms since these groups are both characterized by radical symmetry. The spiney skin of the echinoderms, as opposed to the smooth surface of the coelenterates, is the deciding external factor.

(3) As a final exercise the students should make a large classification tree similar to the one made with buttons. You might suggest that the students use different colors for each taxonomic category and that all similar categories be placed on the same level.



Each box should contain the numbers of the classified animals, using the smallest category only. For example, the mouse is an animal, a chordate, a vertebrate, a mammal and a rodent. The number for the mouse should be placed only in the box labelled Rodentia as this is the lowest category into which this animal is classified.

It is suggested that large sheets of paper be used for this classification tree to prevent crowding.

Additional exercises in classification can be found in most general biology texts. A highly recommended source is the B.S.C.S. (Biological Science Curriculum Studies) Green Version pages 108-113.

Evaluation may be done in a variety of ways, but it is suggested that you do not require the students to memorize an extensive classification system. A practical method of evaluation might consist of presenting the students with a number of objects not encountered before e.g. nuts and bolts, nails, spools, and ask them to design a classification system.

A worksheet exercise is provided as additional review.

Investigation 2 - Naming Living Things

CONCEPTS

1. Because of the great diversity of living things there is a need to name them (this has been briefly discussed in classification T - 6).

2. Living things can be identified by using keys - a more exact means of identification. (This encourages accurate observations).

3. Because the organisms vary, the construction for a key is possible.

4. Variation within a species makes key construction difficult.

Processes Involved

PREPARATION

1. Problem

   Discussion of the problem should be the introduction to the "need" for being able to use a key.
   Refer students to section 3.1, "Living Things can be Named by Using a Key", p. 52, Nuffield Biology Text 1.

2. Background Information

   Students could become familiar with some other simple keys. The key suggested in the text could be discussed using the actual animals to be keyed out. Other keys are included for consideration. See Appendix B.

   It is advisable to spend at least two class periods, allowing the students the opportunity to key out specimens using the keys that are available. In this way, they will have a better understanding of how a key is constructed.

3. Design for Collection of Data

   Instead of making a key using the students as specimens, other specimens, or objects certainly could be used.
   e.g., birds
   various inorganic or organic objects
   leaves
   twigs
   flower heads
   etc.
   The students may wish to develop a chart in which to record their observable characteristics.

   The purpose of using a code name is to allow an evaluation of the student's ability to use a key and to test the key for weaknesses.

COLLECTION AND PROCESSING DATA

The two major headings may be combined in this instance by nature of the design. By carrying out the design the students should be encouraged to organize and record their data in chart form.

PROCEDURE

As the students are carrying out their design it may be advisable to have other simple keys available for reference.

OBSERVATION AND ORGANIZATION OF DATA

Discuss with the students the importance of recording their observations in a neat and organized manner. The development of a format for recording observations must be done before the actual "experimental activity" begins. For each investigation ensure that students know the form in which they will record observations. A chart similar to the one below is given to the students.

A SUGGESTED CHART

STUDENT'S CODE NAME	OBSERVABLE CHARACTERISTICS				
	SEX	EYE COLOR	HAIR COLOR	HEIGHT	

A recommended group size for making the key is 8-10 students. This will provide a diversity of characteristics without the complication of large numbers of students. Students must select characteristics that do not change appreciably with time or their key will not be useful on another day. Students should be encouraged to select characteristics that are most general and that become more specific as the key progresses. Characteristics that are selected should be of the type that more than two descriptions are necessary to identify all persons leaving that characteristic. This is not always possible.

e.g. Characteristic - sex, description - male or female.

To evaluate the student and the applicability of the key, take one member of a group together with the key to another group. Have one of the group identify the code name of the person using the key.

For enrichment to the interested student, they may be encouraged to make a larger classroom key. Other class members could use the key to identify the code name for themselves from the key.

Interpretation of Data

Discuss with the class the qualities of a good key by having each each group make a mimeograph copy available to every other student in the room. Students should be encouraged to point out areas of weakness and confusing descriptions and suggest an alternative method of describing the characteristic.

Some weaknesses in keys are:
- use of negative statements
- insufficient description of characteristic
- vague descriptions through use of adjectives and adverbs open to interpretation, that is, description lacks specificity
- descriptions are too complex

Application

Make use of the various keys that are available which the students can use to identify life forms.

In the interests of "conservation" a teacher may wish to make a class set of the keys that have been included in this booklet and have them returned at the end of each period of use.

Suggestion for evaluation

Students may be asked to make a key of about five to eight biological specimens or pictures that have been selected by the teacher.

Investigation 3 - Living Organisms Show Variation Within Species

CONCEPTS

1. Traits vary from one person to another. Man varies in many outward characteristics. e.g. finger length.

2. The larger the sample of the traits investigated, the more representative the distribution. By measuring the length of the middle finger in a small number of individuals a different curve results from that obtained when a large number is measured.

3. Samples must be selected so that they are representative of the population from which they are drawn.

Processes Involved

PREPARATION

General Problem

Specific Problem:

We would like the students to realize that the general problem is too large to work with and as a result it should be delimited. It should deal with a specific problem which might be investigated to determine that humans do vary.
- There would be a need for discussion on the process Problem.

Class Problem: This problem should be decided upon by the students by means of class discussion.

Suggested Problem - How much do middle finger lengths vary within the class?

Hypothesis

Middle finger lengths will vary. The degree of variation depends on the number of specimens.

Design for Collection of Data

Allow students to design their own experiment.

Class Design

Many of the variables in the design should be discussed with the class.

Example:

1. What do we determine to be the length of the middle finger-where does it start, where does it end. What technique should we use in measuring length.
2. Units to be used in measuring the finger - suggest cm. and to the nearest 5/10 of a centimeter.
3. How many measurements do we make?- Suggest students to separate measurements from students around their station from students in the class (for graphing purposes).
4. How to set up the observation chart to record the measurements.
5. Should point out that procedure in measuring should all be the same and that the student's finger being measured varies.

NOTE: should decide that either left or right middle finger is measured.

COLLECTION AND PROCESSING OF DATA

Again the nature of the design makes it desirable to combine the two major headings.

Procedure

. Observations and Organization of Data

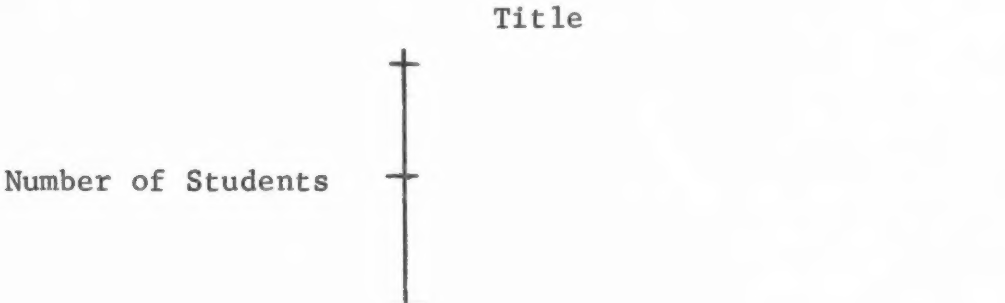
SUGGESTED OBSERVATION CHART

Groups - Middle Finger Length

Student	1	2	3	4	5	6	7	8
a								
b								
c								
d								

. Graphical Representation

- Discuss with the class the two variables involved in making this histogram or bar graph.
- Properly label axis and title both graphs.
- Suggest that one group result is graphed by the teacher as a suggested way of constructing the graph and then allow students to graph their group results and then follow by graphing class results.



- Students could place their graphs on transparencies for class discussion.
- Could also ask students to compare male and female finger lengths using a bar graph. From such a graph possible explanations could be discussed.

CONCEPTUALIZATION OF DATA

Interpretation of Data

1. Students will need guidance in finding the middle finger length for their group.

2. Some discussion should be entered into regarding the normal curve, and the effect population size plays on its shape. (Reference?)

3. - Inaccuracy in reading
   - Difference in Age

4. - Environment factors, e.g., climate, food, predators, population centres
   - Hereditary factors

5. Students could determine the average finger lengths of males and females in the class. The results will vary especially at the grade VII level because of the varying growth rate of boys and girls at that age.

6. Pick sample from one side of the curve, e.g., finger lengths are either longer or shorter than the average.

OPEN-ENDEDNESS

Further Evidence

Students should be introduced to random sampling. They should become familiar with some of the techniques used and made aware of some of the pitfalls, e.g., "biased samples".

1. Nuffield Biology, Text 1: Living Things Vary

2.

3. Eye color
   Hair color
   Height
   Weight
   All variations can not be measured, e.g., color is a qualitative variable.

Application

1. random

2. choice of sample could bias it

3. similar to the one as found in middle finger length of the class and probably closer to the one sketched if all grade seven middle fingers were measured and graphed.

LIVING ORGANISMS CAN BE CLASSIFIED

Investigation 1

PREPARATION

Problem

To develop a system of classifying and apply it to living things.

BACKGROUND INFORMATION

The purpose of this study of classification is to help you develop skill in grouping objects according to their similarities. From these groups you will more easily identify relationships which will help to explain events in the world around you. For example, it may help you to see an order in nature which after a quick look around appears to be so confusing as to discourage a person from attempting to see order in such a multiplicity of plants, animals, and objects. By trying to develop your own system of order in the living world you may develop skills which will help you to order other events in your life.

Diversity Among Living Things

Every day of the week, and especially on holidays, crowds of curious people throng to zoos, aquariums, botanical gardens, and greenhouses. They come to watch lions and elephants, snakes and turtles, sharks and whales, crabs and clams, and plants from every corner of the world. Of course, if you don't live near a zoo, aquarium, or botanical garden, you may visit a forest, meadow, or pond and see hundreds of different kinds of living things.

As you observe living creatures, you are sure, sooner or later, to get an impression of overwhelming numbers of different types of plants and animals. For a casual observer this may only be an impression. But for one who has caught the spark of science, this impression of diversity will arouse questions.

The biologist knows of a diversity of two million different kinds of living things. How can he keep track of such a tremendous assemblage? When the species of organisms far outnumber the words of any language, how can he even find names for them all. And why are there so many different kinds of living things?

Principles of Classification

Before the beginning of agriculture man roamed far and wide searching for game and for edible and medicinal plants. The ability to distinguish useful organisms from those that were dangerous was necessary for survival. By mentally grouping organisms as useful, good, bad, or harmful, early man took the first step in classifying life.

The basic idea of classification is not difficult to grasp. We all do some form of classifying and almost everything may be classified--coins, stamps, clouds, stars, rocks, even the kinds of weather. The words in a dictionary are classified. They are classified according to their spelling--that is, alphabetically. In sorting objects rather than words we could use the same method, classifying according to the alphabetical order of their names. But this is seldom done when large numbers of objects are classified. Rather objects are grouped according to likenesses in the objects themselves.

For the sake of present discussion, let us assume that we have already found a way to separate animals from other organisms. What kind of likenesses may we use in classifying animals.

We might decide to look for a likeness in color. So we group all animals that are blue: blue birds, bluejays, blue whales, bluefish, blue crabs, blue-tailed flies. Or we might pick out likenesses in the number of legs and group together all animals with four legs: frogs, alligators, mice, goats, lions, elephants. Or we might classify animals according to where they live, lumping together animals that are in human households: cats, dogs, canaries, mice, bedbugs, lice, fleas. However, the selection of these and many other kinds of likenesses we might use, have a basic advantage--they do not lead to a consistent series of subdivisions. For example, after we have grouped all blue animals together, we cannot use color for subdividing the group. We must turn to some other characteristic. At least the alphabetical system is consistent--its basis is always the order of letters in the alphabet.

Some organisms are very similar in structure, and others much less similar. Thus we can first sort organisms on the basis of similarities that we consider most important. The importance of the similarities will be determined by the purpose of the classification. Biologists have come to rely upon structural characteristics as a basis for classification. Each sorting of known organisms gives us a new level in the system. The first sorting results in the establishment of the kingdom level. In the scheme of classification adopted by most books, the first sorting gives us only three groups--kingdoms, which we call the animal kingdom, the plant kingdom, and the protist kingdom.

Number of Species in the Different Groups of Animals

Insects	722,000
Spiders	30,000
Animals with Shells	25,000
Millipedes & Centipedes	8,000
Snail and Clam-like Animals	80,000
Microscopic Animals	30,000
Worms	20,000
Other Animals without Backbones	20,000
Animals with Backbones	54,000

Design for Collection and Organization of Data

Exercise I

In order to classify things you will have to know some of their properties. The following exercise will give you practice in identifying properties.

In the sentences below underline the words that indicate properties of the objects in capital letters.

1. SULFUR is a yellow solid and not a liquid.

2. The CANADIAN ONE CENT STAMP is brown and square.

3. QUARTZ is a very hard and transparent mineral.

4. Coniferous TREES are very tall.

5. Some ANIMALS are very large mammals.

6. BUTTONS are very useful.

7. THERMOMETERS are made of glass and contain alcohol.

8. The principal owns a blue Ford CAR.

9. I use yellow CHALK for writing.

10. BOYS like girls.

Exercise II

All objects have properties. Those which have similar properties are put into the same groups. They may also have properties that are not similar. The following exercise will give you practice in selecting the similar properties from the other properties which the objects may have.

GROUP OF OBJECTS	NAME OF GROUP	SIMILAR PROPERTIES	OTHER PROP.
1. peas, carrots spinach			
2. pencil, pen typewriter			
3. thermometer, beaker, graduate			
4. dog, cat, horse			
5. water, alcohol mercury			
6. gold, silver, copper			
7. quarter, dime, dollar			
8. bus, car, bicycle			
9. knife, axe, saw			
10. hammer, nail, tack			

We will try to become familiar with classification by trying to classify a series of different objects.

1. buttons
2. cork and rubber stoppers
3. different shapes, colors and sizes of paper

1. Using any one of the series of objects carefully examine them to determine the features of characteristics that will enable you to categorize or divide them into several large groups. Record these characteristics in the observations.

2. Then break the larger groups into progressively smaller groups with each group consisting of objects of at least one common feature.

3. On a blank piece of paper you can now start the construction of a classification tree. For each group formed write the characteristic common to the group on the classification tree. Devise a name for each group which illustrates the common characteristic of the objects in that group.

4. An evaluation of your classification tree will be performed which will involve placing an object from the same series given by the instructor into your classification tree.

   Note: you must be able to explain the breakdown you follow in your tree.

5. If time permits try and classify one of the other series of objects available by repeating steps 1-4.

Observations

List the features and characteristics that might enable you to categorize or divide the series of objects into several groups.

Interpretation of Data

1. What are some of the things you have to think about and do to develop a classification system? (e.g., What are the characteristics of classification?)
2. List some of the advantages of classification.
3. What are some of the difficulties and limitations in classifying?
4. List some everyday examples where classification systems are used.

Operational Definition

Define classification

APPLICATION

In this section you will apply what you have learned about classification so far, by using "living things".

You are presented with (a) pictures, (b) preserved specimens, (c) live specimens of "living things". These are all numbered.

1. Separate them into two groups--plants and animals. Do the following for each of these two groups.
2. Examine the group carefully (or use your previous knowledge of the specimens) and try to pick out some major characteristics, (e.g., usefulness, habitat, color) which will enable you to divide it into several large groups. Name each group and record these characteristics in your observations chart.
3. Using the large groups obtained from (2) pick out some smaller characteristics to form several smaller groups.
4. If possible, use groups obtained in (3) and form smaller groups. Members of your smallest groups should have at least one common characteristic.
5. Using your observations chart, construct a classification tree. For each group formed write the characteristics common to that group in the classification tree.
6. You can evaluate your classification tree by placing an unknown specimen (obtained from your teacher) in the tree.

7. Now, using external observable structural features (if you have not already done so) construct a new classification tree by following steps (2) to (5).

Observations

(a) Group Name	Specimen Numbers	Characteristics
Step 2		
Step 3		
Step 4		

(b) Classification tree. Your teacher will outline this for you.

Questions

1. There is a commonly accepted classification system. Why is yours different from it?

2. Why is the commonly accepted system superior to yours?

Classification: A Method of Organizing Knowledge

One of the purposes of study of the life sciences is to attempt to discover relationships that give meaning and order to things which often times seem very haphazard and unrelated. Without some kind of a classification system, the world of living things would seem to be just a tremendous number of unrelated things.

A classification system may be developed by an examination of likenesses and differences. One may classify living organisms by looking at very general differences such as the presence or absence of chlorophyll. Each of the several individuals of these two groups are alike in possessing the same general characteristics; but they may still differ in other features. One may take specific differences and separate the individuals further, forming subgroups. For example, animals are classified into vertebrates, animals with backbones and invertebrates, animals without backbones. The vertebrates are further divided into subgroups by the examination of more specific structures. We recognize these subgroups as fishes, reptiles, amphibia, birds and mammals. Each of these subgroups may be divided into smaller and smaller groups according to more specific characteristics.

It has been largely by the process of looking at likenesses and differences that man has been able to give order to seemingly unrelated, isolated, observations. This method of observing, describing, and looking for similarities and differences may be used to classify rocks, minerals and any of the things found in the universe. As man discovers relationships that exist amongst living things in the environment, he organizes his knowledge of the environment.

One of the first attempts to classify all living things was made by a Greek philosopher, Aristotle, who lived more than 2,200 years ago. However, Aristotle thought that there were only a few hundred animals in the world. As man explored new lands he found animals that could now be placed in Aristotle's scheme of classification.

About two thousand years later, in the year 1735, a Swedish scientist, Linnaeus, made one of the first important attempts to classify both plants and animals. He started by giving each kind of organism two names; a name for its genus, which is a kind of surname, and a name for its species, which is a kind of Christian name. This is the Binomial System of naming things.

Using the idea of grouping by likenesses and differences, scientists have developed a system of subdividing living materials into groups that is used by the other scientists of the world. If one proceeds from the more general likenesses to the more specific lineness the groups are:

Kingdom
Phylum
Class
Order
Family
Genus
Species

Classification is an easy way to store information about objects. If you know that an object belongs to a certain group, you can predict what properties that object will have. e.g., If you know that a dog is a mammal, you will predict that it is covered with fur, is warm-blooded, suckles its young, has a four-chambered heart, etc.

The table below shows the classification of man, the adder (snake), the earthworm and the beech tree.

GROUP	MAN	ADDER OR VIPER	EARTHWORM	BEECH TREE
Kingdom	Animal	Animal	Animal	Plant
Phylum	Vertebrata	Vertebrata	Annelida	Spermotophyte
Class	Mammalia	Reptilia	Chaetopida	Angiospermae
Order	Primates	Serpentes	Oligochaeta	Fogales
Family	Hominidae	Viperidae	Lumbricidae	Fogaceae
Genus	Homo	Vipera	Lumbricus	Fogus
Species	H. sapieus	V. berus	L. terrestris	F. sylvestris

Each individual plant and animal is known primarily by its genus and species name, just as you are known by two names. The genus name comes first and is always capitalized, it is like your last name. The species name is written after the genus name and is not capitalized. In addition the genus and species name is either italicized or underlined. Here are a few examples:

(1) Dog Genus - Canis
Species - Domesticus
Therefore: Canis Domesticus

(2) Man Genus - Homo
Species - Sapiens
Therefore: Homo Sapiens

CLASSIFICATION EXERCISE

You are, by now, familiar with the need for classification in order to organize information. Below you will find groups of characteristics common to certain groups of animals. Your teacher will go over it with you to explain all unknown terms.

1. Look at the specimens you have before you and decide to which group each specimen belongs. Place the number of the specimen in the blank next to the appropriate group of characteristics.

2. If you know the name of the animal place this in the appropriate blank.

3. When you have finished grouping your specimens go to the next station and follow the same procedure for these animals.

4. Design a classification tree using numbers rather than names when grouping your organisms.

TAXA	CHARACTERISTICS	SPECIMEN NO.	COMMON NAME
I. KINGDOM	ANIMALS	ALL	
Subkingdom	INVERTEBRATA - animals without notochords or backbones		
1. PHYLUM	PORIFERA - all sponges - many celled, stationary organisms - live in water - single body cavity with many pores in the body wall - very simple		
2. PHYLUM	COELENTERATA - radially symmetrical animals with a hollow body cavity - they have a single opening for taking in food, and excreting wastes - they all live in water - they have a soft, squishy appearance		
3. PHYLUM	PLATYHELMINTHES (Flatworms) - bi-laterally symmetrical - flattened dorsoventrally - very often they are parasites - they are unsegmented - only one opening into the gut		
4. PHYLUM	MENATHELMINTHES (Roundworms) - all round worms whose bodies are not segmented - they have a body cavity		
5. PHYLUM	ANNELIDA (segmented worms) - worms having their bodies divided into ring-like segments of uniform shape - they have both a mouth and an anus		

TAXA	CHARACTERISTICS	SPECIMEN NO.	COMMON NAME
6. PHYLUM	ARTHROPODA (Jointed legged animals) - Arthropods are closely related to annelids - their body is segmented and some or all of the segments bear paired appendages - these jointed appendages themselves are also segmented - the animal has a hard outer skeleton		
(a) CLASS	TRILOBITA (Three-lobed animals) - Extinct arthropods found only as fossils - their body is divided into three distinct parts, longitudinally - the body can be rolled up		
(b) CLASS	CRUSTACEA - water dwelling arthropods - they have two pairs of antennae - many crustacea have a pair of large clawed appendages		
(c) CLASS	MYRIAPODA (Many Legs) - land living arthropods with long bodies and many legs - they have a distinct head and one pair of antennae		
(d) CLASS	INSECTA - six-legged arthropods whose body is divided into three distinct regions: head, thorax and abdomen		
(e) CLASS	ARACHNIDA (Spider Group) - arthropods with no antennae and with only two body segments - some primitive members are horseshoe-shaped - many have stingers in their abdomen		

TAXA	CHARACTERISTICS	SPECIMEN NO.	COMMON NAME
7. PHYLUM	MOLLUSCA - most aquatic, soft bodied animals with a hard shell - they are unsegmented - they have a head and a muscular foot		
(a) CLASS	AMPHINEURA - molluscs with a long bilaterally symmetrical body - they have no eyes or tentacles		
(b) CLASS	GASTROPODA (Stomach - foot) - molluscs with a head and tentacles and with a coiled shell		
(c) CLASS	PELECYPODA (Hatchet Foot) - molluscs that have a bilaterally symmetrical body enclosed in a bivalved shell		
(d) CLASS	CEPHALOPODA (Head - foot) - molluscs with a well developed head which is surrounded by a crown of tentacles - eyes are well developed		
8. PHYLUM	ECHINODERMATA (Spiny-skins) - radially symmetrical animals which have spiny skins - many have tentacles and are star-shaped		
9. PHYLUM	CHORDATA - animals with a nerve cord along their backs - higher chordates have a bony backbone (Vertebrate) - these are often called the "higher animals"		

TAXA	CHARACTERISTICS	SPECIMEN NO.	COMMON NAME
(a) CLASS	AGNATHA - vertebrates without jaws - long and snake-shaped with a round circular mouth used for sucking		
(b) CLASS	CHONDRICHTHYES - cartilaginous fish such as sharks and rays in which the backbone is not yet made of bone		
(c) CLASS	OSTEICHTHYES - true bony fish with the body covered with overlapping scales - the gills are covered by a flap - the lobes of the tail fin are equal in length		
(d) CLASS	AMPHIBIA - vertebrates which spend part of their lives in water and part on land - they breath by means of gills during some part of their lives though some adults breath mostly by lungs - they all have paired limbs		
(e) CLASS	REPTILIA - cold-blooded vertebrates with scale covered bodies and clawed toes - they breath by means of lungs and are mostly land animals - all lay eggs - they have horney beaks		
(f) CLASS	AVES - vertebrates with feathers - they have paired limbs with the anterior pair usually developed into wings - they have horney beaks and scale-covered legs - they lay eggs		

TAXA	CHARACTERISTICS	SPECIMEN NO.	COMMON NAME
(g) CLASS	MAMMALIA - vertebrates with true hair - they are warm blooded - have mammary glands for producing milk - the young are born alive		
ORDERS	Some major mammalian orders will now be listed. You should find some background information on each order so you will know what kind of mammals these orders represent		
i ORDER	MARSUPIALIA		
ii ORDER	INSECTIVORA		
iii ORDER	CHIROPTERA		
iv ORDER	PRIMATES		
v ORDER	CARNIVORA		
vi ORDER	RODENTIA		
vii ORDER	CETACEA		
viii ORDER	PROBOSCIDIA		
ix ORDER	UNGULATA		
x ORDER	LAGOMORPHA		

GRADE 7 CLASSIFICATION WORKSHEET

1. What is classification?

2. Why do biologists classify organisms? Give at least three reasons.

3. What is the main characteristic that biologists use to classify organisms?

4. Why do biologists use Latin in naming organisms?

5. Name the Swedish scientist who made one of the first important attempts to classify both plants and animals.

6. What are the scientific classification groups proceeding from more general likenesses to more specific likenesses?

7. Classify the house cat using the following groups:

KINGDOM

SUBKINGDOM

PHYLUM

CLASS

ORDER

FAMILY

GENUS

SPECIES

8. What is one characteristic of the following groups:

PHYLUM - ARTHROPODA

CLASS - INSECTA

CLASS - CEPHALOPODA

ORDER - INSECTIVORA

9. True or False

	T	F
a) Cephalopods are a class of arthropods		
b) Trilobites are modern aquatic creatures		
c) All annelids are segmented		
d) Platyhelminthes are bi-laterally symmetrical		
e) The sea cucumber is an echinoderm		
f) Amphibians belong to the subkingdom Invertebrata		
g) Reptiles are warm-blooded vertebrates		
h) Marsupialia is a mammalian class		
i) Rabbits are a type of rodent		
j) The shrew is the smallest living mammal		

10. Define the following terms:

a) Dorsal

b) Bi-lateral symmetry

c) Insecta

d) Thorax

e) Nutrition

NAMING LIVING THINGS (keying)

Investigation 2

Problem

To construct and use a key for the purpose of identifying specimens.

Background Information

To become familiar with a key and how it is used, carefully read section 3.11 "An Imaginary Key", p. 53, Nuffield Biology, Text I.

Because of the difficulties scientists run into when naming things, a useful tool called a "key" has been developed. These keys consist of a series of questions which in turn, will yield the correct name of the specimen you are attempting to identify.

They key is built using pairs of characteristics. You will select one of the characteristics and reject the other. To the right of the characteristic there is a number. This is the number of the next pair of characteristics you are to consider. You will select one of the pair of characteristics as being common to the specimen and proceed to the next set of characteristics, as indicated by the number on the right. If the key is used properly you will arrive at the correct name for the specimen.

The process of using the key outlined above is repeated for each of the specimens you are attempting to identify.

Design for Collection of Data

Construct a key which could be used to identify the students around your station. Follow the suggested design.

1. Make a list of some of the observable characteristics which would help you distinguish each member around your station. Record these in an observation chart. See observations.
2. If you can think of any other important features, then make more columns along the top of your chart.
3. Identify each member around your station by a code name in the appropriate column.
4. When you have filled in the necessary information in each column by check marks, select pairs of observable characteristics which are opposite or different from each other. e.g., a) face has freckles
   b) face lacks freckles
5. You are now ready to make the key itself. If you are in doubt about how to proceed, have a look at the key in section 3.11 in the text or any other key.

Procedure

Follow the design and record any changes and additions which were not foreseen in the design.

Observations and Organization of Data

To record your observations in a neat and organized way use a chart similar to the following:

Students' Code Names	observable characteristics							
	sex		eye color		hair color		height	
	male	female	blue	green	blonde	brown	short	tall

Interpretation of Data

Write the finished key in the space provided.
Note: A good key is one which will easily identify the specimen.

New Problems for Investigation

A problem in making a key which often causes trouble is how to select for comparison of plants and animals which can be described as "typical" of the group to which they belong. Explain the above statement. Hint: refer to p. 56, NFI.

Application

Identify the specimens given to you by your teacher using the keys provided.

LIVING ORGANISMS SHOW VARIATION WITHIN SPECIES

Investigation 3

General Problem

How do we vary?

Specific Problem

Class Problem

(To be decided upon after class discussion on the specific problems.)

Hypothesis

Design for Collection of Data

Design an experiment which will help you to answer the class problem.

Student Design

Design a procedure that will work in the laboratory. Be sure to indicate the steps to be followed, the material needed, and how you are going to record your observation.

Class Design

Procedure

Follow the class design and record any changes and additions which were not foreseen in the class design.

Observation and Organization of Data

Construct the necessary charts to record your data. Keep in mind that we want to record your station's results separate from the rest of the class members. (Indicate which results are male and female middle finger lengths.)

Graphical Representation

1. On graph paper construct a bar graph showing the number of students in your station who have the same middle finger length.
2. On another piece of graph paper construct a bar graph showing the number of students in your class who have the same middle finger length.

Note: Do not forget to label the axis and title the graph.

Interpretation of Data

1. What is the average middle finger length of your group?

2. What do you think the curve of the graph would be if we plotted the middle finger lengths of all the grade sevens in the school? (sketch the curve and explain)

3. List some of the experimental errors which possibly were encountered in the process of collecting data.

4. List some of the factors which may cause species to vary? (Why do middle finger lengths vary within our classroom?)

5. How do female middle finger lengths vary from male middle finger lengths? Support your answer with evidence.

6. What kind of sample could you pick that would give you a distorted representation of your population?

Further Evidence

1. Read the last two paragraphs on pages 56-57 in 3.15, Living Things Vary, Nuffield Biology, Text I.
2. Explain the following statement, "In developing a key you rely on certain constant features within a species. Because of the variation of plants and animals within a certain species a technique of random sampling must be devised - one in which variety within the sample is likely to be distributed equally on either side of the average".
3. List some of the other things which vary in man other than finger length. Can all variations be measured?

Application

1. If you had a population of 100 field mice from which you were to choose only ten for a study on tail length, how would you go about selecting your sample?

2. In what way could your sample be biased?

3. What kind of curve would you expect to find if the tail lengths of 100 mice trapped in a field were graphed?

UNIT III

MICROBIOLOGY

The Use and Care of the Microscope

As an introduction, students could do their own research reports on the history of the microscope or this may be discussed in class by the teacher.

HISTORY OF THE MICROSCOPE

To see very small objects one has to use a microscope. Scientists have always been interested in the structure of living things but have not always had the instruments with which to see the units of which living things are built. The history of the microscope illustrates very clearly that often it is not easy to develop new instruments, and that the effort of many people is required.

590 B.C.	Euclid investigated some properties of curved reflecting surfaces.
65 A.D.	Seneca: Glass spheres filled with water "will aid in seeing those difficult things that frequently escape the eye".
1235	Roger Bacon: The invention of spectacles
1485	Leonardo da Vinci stressed the importance of using lenses for examining small objects.
1590	Jans and Zacharias Janssen put together a concave and a convex lens in a single tube, making what we now call a Galilean telescope (or microscope, if used the other way around).
1609	"The Academy of the Lynx" (possibly the earliest scientific society) founded in Italy by Federigo Cesi, Duke of Aquasparta; the lynx was supposed to have very acute vision. The word "microscope" was coined by one of its members (Johannes Faber of Bamberg). The earliest published accounts of the indusia of ferns, and of the external anatomy of honey bees, were published by the Academy. This was the first time that illustrations were used in a book which were prepared with the aid of a microscope.
1660 onwards	Marcello Malpighi, Professor of Medicine at Bologna, first saw capillaries in the lung of a frog by washing the blood away with water injected into the pulmonary artery; later he watched capillary circulation in the mesentery. He also did important embryological work on the chick, and produced the first monograph on the anatomy of an invertebrate (a treatise on the silkworm). The main bulk of his published work was on plant anatomy: the structure of xylem elements, the distinction between monocotyledonous and dicotyledonous stems, and between herbaceous and woody ones. He illustrated Xylem fibers, resin ducts, pitted vessels, and tyloses and was the first to see and draw stomata found on the under surfaces of leaves.
1660 onwards	Jan Swammerdam: A brilliant dissector whose figures of the structure of insects (such as mayflies, bees and mosquito larvae) and many other animals were mainly published posthumously as the Bible of Nature in Leyden in 1737 - '38.
1632 - 1723	Antony van Leeuwenhoek, the son of a basketmaker, spent most of his life in the Dutch town of Delft. He was a draper by trade but reserved his energies for his hobby of grinding lenses and making

Adopted from: Interaction of man and the Biosphere, BSSC Green Versions 1969
Life Science Committee and units by Norm Werenka.

microscopes. Working with simple microscopes of very high magnification, Leeuwenhoek published many observations on a wide variety of subjects: The capillary circulation, red cells of fishes, frogs and mammals, structure of muscles, teeth, skin and the lens of the eye. He studied the compound eyes of insects, aphid life histories, the development of ants, the spinnerets of spiders, and also published the first figures of bacteria and papers on Protozoa, Volvox and rotifers. All this he did with a powerful hand lens.

Anton van Leeuwenhoek had the bright idea of mounting a high powered lens (only an inch across) instead of holding it in his hand. The object to be examined was mounted on a pointed rod which could be moved up or down, and nearer or further away from the lens, by means of two screws. This arrangement overcame the problem of movement of the object. (Refer to Nuffield Biology, Text II, p. 3 shows a copy of Leeuwenhoek's original microscope.)

By modern standards these early microscopes were poor. The pictures produced were not very clear and the magnification quite low. An ordinary school microscope will magnify objects 400 times without difficulty, while good instruments have magnification of x 1,000 or even more.

THE USE OF A MICROSCOPE

1635-1703 The kind of microscope we use today was first made by Robert Hooke. He described his microscope in his book Micrographia, which includes many illustrations of objects which he had seen with the aid of this instrument. (Figure 36 in Nuffield Biology, Test I, p. 62, shows Hooke's drawing of a flea.

Parts and use of a microscope can be domonstrated by the use of a diagram on the overhead projector as well as breaking down part-by-part a microscope used in the classroom. After discussion students can label their own diagrams and do further exercises.

Preparing slides can be demonstrated by use of diagrams and actual preparation by the teacher.

THE BIOSPHERE

The purpose of the first few pages is to immediately focus students' attention on one major theme of the course, man's interaction with other organisms in the biosphere.

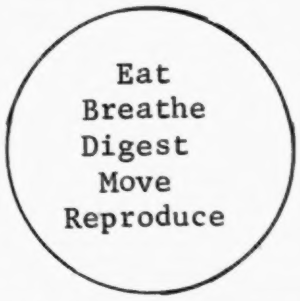
Question:

1. The arrows point from eaters to eaten. It is easy to see that cats eat rats. But students may have difficulty in understanding that the malaria organism gets its nutrition from (eats) both mosquitoes and man.

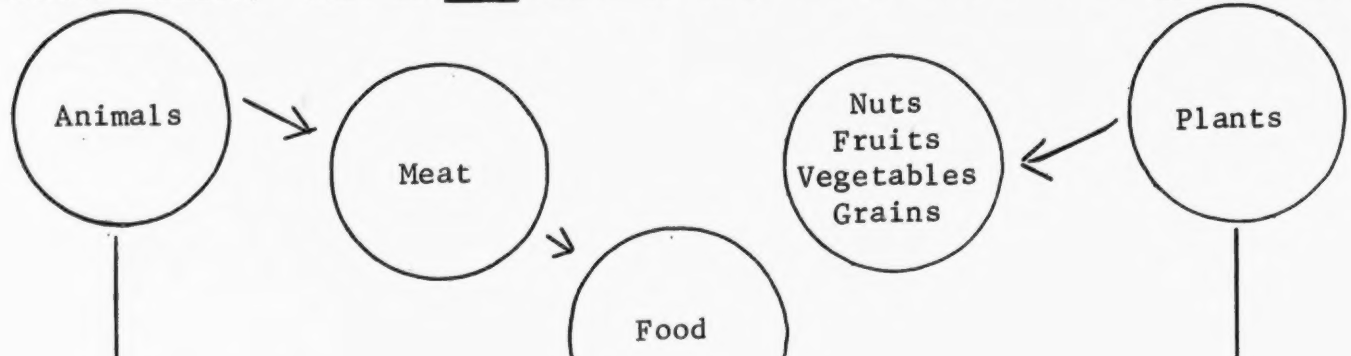
Investigation 1

The first paragraph asks, "Are all these objects alive?" This question can serve as the basis for a class discussion on the characteristics of life. You might begin by asking, "Are you alive?" Assuming that the answer will be "yes", go on to ask, "What leads you to say that you are alive?" Hopefully, the discussion will become general. As it does, make a simple diagram on the board to summarize the major points:

LIVING THINGS


Eat
Breathe
Digest
Move
Reproduce

The students should agree on all the important features that they regard as characteristic of life. Then gradually extend the discussion to man and his dependance on the environment: What does man breathe? What does he eat? Where does wood for houses, fiber for clothes, etc., come from? If part of his food is "other animals," what do they eat? If they eat plants, what do plants eat?


Animals
Meat
Nuts
Fruits
Vegetables
Grains
Plants
Food
Air
Man
Wood
Wool
Hides
Silk
Textiles
Leather
Water
Cotton
Linen

Interaction of Man and the Biosphere, Second Edition, Rand McNally and Company.

At this stage it is not necessary to interject biological facts not already known by students. Let the diagrams be the students' and in their words. But with your guidance it should be possible to extract from the class the overall ideas that:

> Some things are alive - others are not. (There are general characteristics separating the two classes; however, at this time it will probably be impossible for students to give definitions of life and nonlife that can be applied to all things.)
>
> Man's life is completely dependent on other organisms and on the nonliving environment. Try to introduce students to the philosophy that man is not the arrogant master of the biosphere (or at least he cannot always be), but only one of many interdependent forms of life.
>
> The biosphere is made up of complex interrelations among things and events.

Also, try to lead students to ask broad, philosophical questions, such as:

> What is life? What is man? How does man interact with the biosphere?

Investigation 2

MINI-BIOSPHERES[2]

We believe that students should become involved in laboratory activity very early in the course. Class discussion should reinforce the need for careful observation, accurate record keeping, and laboratory safety.

Students should eventually observe many different kinds of organisms in the biospheres. Students should not be told that they will see organisms in all the biospheres. Allow them to discover this.

Since several days may elapse before many organisms are visible, students are asked to learn how to use the microscope, as outlined in the guide. You may wish to use prepared slides or bits of lens paper to aid students in learning the proper use of a microscope.

This investigation introduces some of the questions about the biosphere that will be studied throughout the year.

Materials:

Large bacteria, many kinds of protozoa, algae, and other organisms are visible under 100 power magnification. We recommend that at least one microscope be available for each team of four to six students.

Students should be asked to provide the baby-food jars and materials.

Procedures:

Chlorinated water may inhibit the growth of microorganisms. Sterilized water from a pond, stream, or aquarium may be preferable to tap water. If you have to use tap water containing chlorine, put it in a pan or other open container a day before it is to be used.

Students should be given latitude in choosing both the kinds and amounts of dry grass.

[2] Interaction of Man and the Biosphere

If tap water is used, students should not find many organisms for the first two or three days. Beginning on the fourth day, many motile bacteria and a few protozoans should be visible. As the number of protozoans increase, the number of bacteria may decrease. But do not force a discussion of succession at this point. If students have difficulty finding organisms, suggest they take the drop from the surface scum or from the water just under the surface.

Interpretations:

1. The purpose of the questions is to stimulate discussion and the formulation of questions. Point out to the students that a most difficult job, but one which must precede any scientific effort, is the asking of questions. It is hoped that your discussion with students will elicit questions which can serve as their own outline of the year's course. You might place the list of questions on a large piece of butcher paper and display the list in the room so that students can keep track of their progress during the year. You might use the left side of the paper for listing the questions, the right side for adding brief answers as they become available. Among the questions students may pose (although not necessarily in the same words) are the following:

Questions	Answers
1. Where did the moving objects come from?	
2. What do they need to live?	
3. What is happening inside the organisms?	
4. What determines their individual characteristics?	
5. What determines how many of each kind will grow there?	
6. What are the names of the organisms?	
7. How do they reproduce?	
8. How does the composition of the biosphere change?	
9. How does the environment affect the organisms?	
10. How do organisms affect their environment?	

Students will note as the year progresses that they think of more questions than answers. Hopefully, you will find an opportunity to point out that the "answers" usually are only tentative, and that more information is usually required before acceptable answers are found.

We recommend that all ideas and suggestions from students be honored, even if they are wrong. Try to let the course develop into a self-correcting experience. Scientists must revise opinions as new data is collected - why shouldn't students learn the same approach?

The purpose of the question where does life come from is to allow students to consider the possibility of spontaneous generation -- life arising from nonlife.

Do not use the term "spontaneous generation" at this time. Give students a chance to give their ideas about the origin of microorganisms. During the eighteenth and early nineteenth centuries, one of the greatest scientific controversies of all time was carried on between scientists who believed in spontaneous generation and those who did not. Many texts treat the subject as though scientists of that era were rather stupid. Redi is given some credit, and Pasteur final credit, for demonstrating that life, regardless of kind, arises from pre-existing life and that experiments show the theory of spontaneous generation to be incorrect.

We believe that students should be allowed to make the kinds of observations that led to a belief in spontaneous generation. How else can one explain how bacteria and protozoa gradually appear in a jar of water to which dried grass has been added? If students are to understand science they must experience science - not just be told about it.

Student answers might include:
"They came from the air".
"These organisms live in dried grass".
"These organisms live in water".
"The dried grass turned into organisms".

It is unlikely that students will suggest the presence of spores. Even if they do, it is unlikely that they will know what the term "spore" means.

You may wish to ask students how they might "prove" how the organisms got into the water. Students should be encouraged to design and carry out experiments that will support their ideas.

Some students may suggest that the dried grass provides nutrient material for microorganisms. Do not press for "correct" answers. Encourage students to express their ideas freely and without fear of being wrong.

> NOTE: Students will vary in their ability to find microorganisms. Microscopes with 200-400 power magnification and good optical quality will yield the best results. If microorganisms are not found by the third or fourth day, it is likely that the water contained something poisonous to them.

For Further Activity:

1. Cultures of protozoans, algae, crustacea (Daphnia), hydras, and other organisms may be purchased from biological supply companies. Use of these cultures will provide a richer experience for students. If cultures are ordered, sterile culture medium should be prepared in advance. The pure cultures should be subcultured within a few days after they arrive.

2. Students should be encouraged to bring in samples of water from stagnant ponds and to examine drops of pond water through the microscope. Interested students may wish to continue their study of poind water with the aid of the illustrated key of pond water organisms in some text.

Investigation 3

The main purpose here is to find that living things are made of cells. Students should be allowed to come up with main differences such as the cell wall and chloroplasts, otherwise it gets too technical.

As an optional exercise have prepared slides for them to identify as plant or animal.

Procedures

The elodea leaf must be a young leaf from the growing tip. If an older leaf is used, not enough light will be transmitted, and students will not see the cell. Cells with few chloroplasts generally provide the best opportunity to observe cell structure.

Warn students to use care in scraping the insides of their cheeks. Individually wrapped sterile toothpicks are recommended.

Interpretations

Students should detect cell walls in the elodea leaf but not in the animal cells. They may see other different characteristics such as color, shape, etc. These additions can be added to their chart.

The thickened outer portion of plant cells could contribute to the rigidity of most plants. Allow students to speculate on this possibility for now.

Investigation 4

Students have a question that (for them) can only be answered through planning, investigating, observing, and interpreting. Note that little direction is given as to how they should proceed. Throughout the course, students will be encouraged to think for themselves - to use their imaginations and creative abilities. This does not mean that the teacher should let students "do what they want" or allow them to use purposeless laboratory activity as a means of avoiding serious effort to learn. To the contrary, the teacher must use his own creative ability in giving guidance where needed and in drawing from students their ideas for carrying out investigative work. To the extent that this is done, the investigations should provide students with a sense of involvement in science and bring them a large step closer to understanding the nature of science.

Materials

The unknown materials should include sand, brown sugar, powered yeast, radish seeds, and table salt. Provide each team with about a teaspoonful of each material.

Magnifying glasses can be obtained locally at a variety store or purchased from a scientific supply company.

Chemicals needed are table sugar and molasses. Prepare a molasses solution by adding 100 ml. molasses to a liter of water. Prepare a sucrose (table sugar) solution by adding 200 grams of sucrose to a liter of water. Stopper and label the containers. These quantities should be enough for one class.

Glassware should include test tubes and beakers (or baby-food jars).

Procedures:

A. The list will be essentially that prepared in previous class discussion.

B. Have students copy the chart in their notebooks. Considerable class interest can be stimulated by having students predict which materials are alive. They can then test their predictions experimently.

C. Students should be given as much opportunity as possible to suggest their own approaches to "solving the problem". Be prepared to give guidance where needed.

Suggestions in student material --

1. If the materials are placed in water, in one test the water should be about one millimeter deep. (Tests with more or less water may provide an interesting comparison). Radish seeds begin to sprout in about three days. Most students will have predicted that the radish seeds are alive, and the appearance of the sprouting seeds will give them confidence in their prediction. The other objects should not show evidence of life when placed in water.

2. Students are not likely to see a positive indication of life by viewing the materials under a microscope.

Additional suggestions to be offered as needed.

1. Plant each of the materials in soil. Water each day and look for plant growth.

2. Place a small amount of each material in a jar or beaker containing dilute molasses solution. By the next class period, the solution containing yeast should show the evolution of bubbles. This indicates that some kind of a chemical reaction is taking place. It does not necessarily prove that living things are present.

3. Place about ½ teaspoon of each material in baby-food jars (or small beakers) about half-filled with sucrose solution. Within one class period the solution containing yeast will be frothy and may flow over the edge of the jar. During the next class period have students smell each container and record their observations.

4. You may wish to have students examine material from the molasses and sugar solutions under a microscope. They should see yeast cells - some in the budding phase.

Interpretations:

1. Student answers will vary. Many should predict radish seeds as living things. A few might guess that the unknown containing yeast is living material.

2. Their investigation should yield evidence that two of the unknowns are alive. This is not proof that the other materials are not living. It only indicates that the tests failed to show signs of life in anything but the radish seeds and yeast.

Optional Investigations:

The following investigations may be used for supplemental material as the teacher sees fit. For this reason, they are included in the teacher's noted. It should be noted, however, that no guidance is given to the teacher for the use of these investigations.

Three sets of investigations are included: Set A - Yeast
Set B - Molds
Set C - Bacteria

SET A - LOOKING AT YEAST

Yeast Cells

1. Using one test tube, mix a solution of water and yeast.
2. Pour in 5 c.c. of solution in test tube.
3. Make a slide using a small drop of this mixture and adding a dye to the slide.
4. Observe under microscope.

Questions:

1. What does a yeast cell look like?

2. Draw a picture of several cells.

3. How can you tell the difference between a yeast cell and a small air bubble?

4. Observe and give an approximate number of yeast cells in the whole field.

Measuring the Size of a Yeast Cell:

1. On another glass slide measure 2 m.m. across the slide and mark with a felt pen as illustrated in the diagram.

2. Once this space is marked use the other side of the slide and place another small drop of above solution.

3. Then count approximately the number of yeast cells that will fit between the 2 lines which are already marked at 2 m.m. in distance.

4. Given that if 1 m.m. equals 1,000 microns, how many microns in 2 m.m.?

5. Divide number of cells you found in #3 into the number of microns in #4. This answer will be the size of each cell.

$$\frac{2 \times 1{,}000 \text{ microns}}{\text{number of cells}} = \text{the size of each cell.}$$

Does Yeast Make Its Own Food?

Problem: Does yeast contain chlorophyll?

Hypothesis:

Collection of Data: Use ¼ of a test tube of alcohol and mix yeast.

Procedure: (Draw diagrams for all observations)

Observations:

A) of the yeast
  1. What color is yeast?
  2. What color is chlorophyll?
  3. Is yeast the same color as chlorophyll?

B) of the alcohol
  1. What color does the alcohol turn to?
  2. Is this the color of chlorophyll?

Interpretation of Data:

Conclusion of Results ---

1. Why was alcohol used to find chlorophyll?

2. Plants need chlorophyll to ______________ ______________

3. Does yeast contain chlorophyll?

4. Does yeast make its own food?

5. What food do you think yeast would use to live and multiply?

6. Yeast, molds, and bacteria belong to a subphylum called _____

7. What simple plant that we have studied in the Phylum Thallophytes does contain chlorophyll?

Food For Yeast

Green plants that make their own food contain chlorophyll. Yeast does not contain chlorophyll, thus assumed it does not make its own food.

Yeast must obtain its food from a host thus it is often called a parasitic plant or fungus.

From specimens in class we find that often a fungus lives off other green plants that make their own food, namely sugar.

Problem: Will yeast feed on sugar?

Prediction:

Collection of Data: Four containers are used.

A. control: a sugar + yeast solution - at room temperature
B. experimental: a yeast and sugar solution - heated
C. control: a yeast solution - heated
D. control: a sugar solution - heated

Stage 1 (draw diagrams for all observations)

Using the sets of diagrams on General Procedure:

1. Mark 4 test tubes A, B, C, D, with the marking pencil supplied.
2. Add a vile capful of yeast to tubes A, B and C.
3. Add to tubes A, B & D ¼ test tubeful of sugar solution.
4. Add ¼ test tubeful of plain water to C.
5. Over each of the test tubes place a balloon as in diagram.

Observation: Stage 1 (Using only A & B)

Tubes A & B 1. At room temperature is the yeast & sugar solution of A or B bubbling?

Room Temp. 2. Is either balloon inflated at all?

3. If so, would you say the solution is making a gas?

Stage 2 (draw diagrams for all observations)

Tubes A & B 1. Place yeast and sugar solution "B" in a hot water bath at the front of the class for five minutes.

Heated B 2. Take out of bath and record your observations of "B".

3. After another five minutes record your observations for "B".

Observation: Stage 2

1. What is happening in: Test tube A?

   The balloon over A?

2. What is happening in: Test tube B?

   The balloon over B?

Questions

1. What causes the balloons to be filled?

2. Which balloon is blown up faster - A or B?

3. Does yeast react with sugar?

4. Did heat speed up the reaction?

5. Why were both tubes A and B used and not just B?

6. What was the variable involved or tested here?

Stage 3 (draw diagrams for all observations)

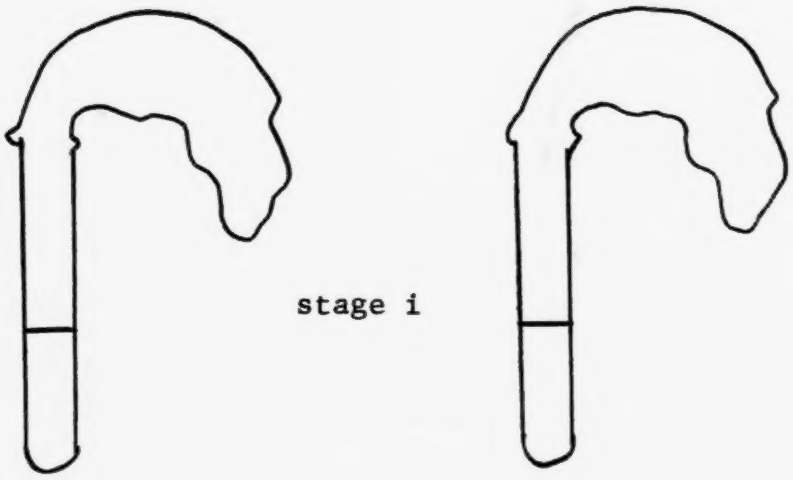
Separate sugar solution and yeast solution heated

1. Place test tubes C and D in the water bath at front of class for 5 minutes.
2. Take out of bath.
3. Record results in observation.

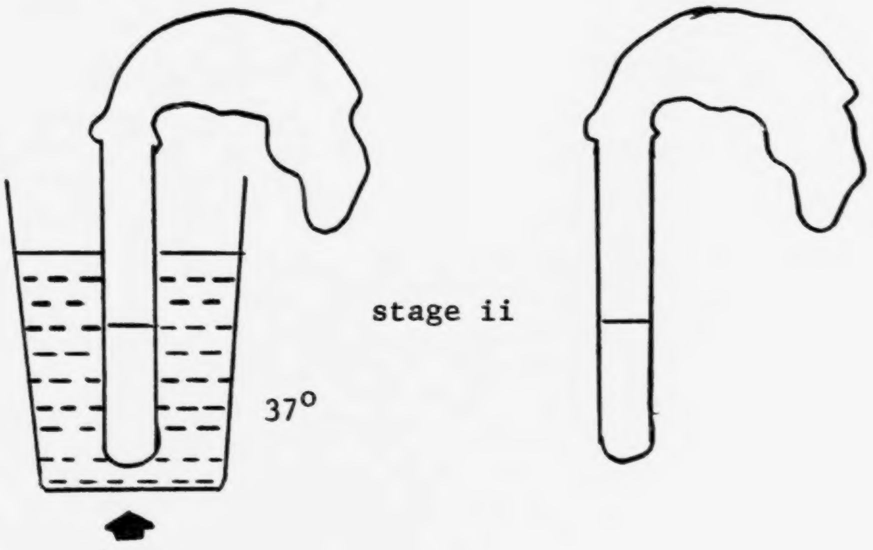
Observation: Stage 3

1. What has happened to the balloons on C and D?
2. Are they partly filled?
3. Was there as much of a reaction as with the sugar and yeast solution which was heated in B?
4. Why were test tubes C and D used in the experiment, not just A and B?

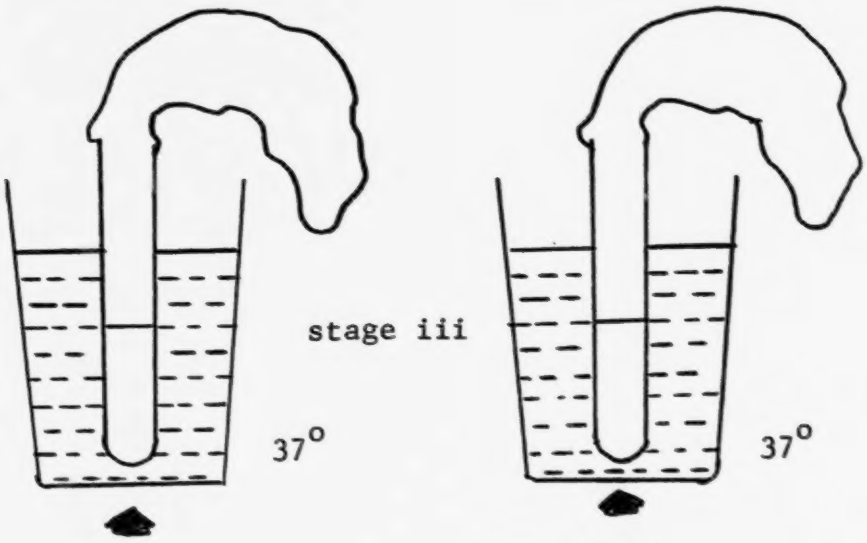
1. SAVE TUBES "B" AND "C" FOR NEXT EXPERIMENT.
2. TAKE OFF ALL BALLOONS AND CLEAN REST OF EQUIPMENT



A. sugar solution & yeast B. sugar solution & yeast


stage ii
37°
heat

A. sugar solution & yeast B. sugar solution & yeast


stage iii
37°
37°
heat
heat

C. yeast solution only D. sugar solution only

WHAT DOES SUGAR DO FOR YEAST?

Problem

Does yeast feed on sugar?

Background Information

From the last experiment you saved "A", a yeast and sugar solution and "C", a plain yeast solution.

Remember yeast is a plant and sugar is a chemical.

Hypothesis

Collection of Data

Using the two solutions from the last experiment, compare the tubes in light and use the microscope to compare the solutions.

Procedure

(Draw diagrams for all observations.)

Stage 1

1. Take the two tubes B and C from the lab - do not shake or disturb the tubes.
2. Hold both tubes up to the light and compare to see which solution is the most transparent.
3. Hold a piece of plastic with writing on it behind each tube and compare transparency of solutions.

Observations

1. Which tube appears to be more cloudy in appearance - tube B or tube C?
2. What is contained in tube B?
3. Which solution appears to be thicker?
4. Which solution gave the greatest reaction in the last experiment?
5. Which solution (a) the yeast & sugar } would you say had more
   (b) the yeast } yeast cells?

Procedure - Stage 2

1. Label a glass slide with yeast.
2. Using an eye dropper, fill it partially with the yeast solution (C).
3. Place three separate drops on above glass slide.
4. Wash out the eye dropper in a beaker of water.
5. Label another glass slide with yeast & sugar.

6. Using the eyedropper again, place three separate drops of the yeast & sugar solution "B" on the glass slide.

Procedure - Stage 3 (draw diagrams for all observations)

Using the microprojector at the front of the class, compare the two slides.

Observations - Stage 2 and 3

1. Which drops appear to be darker, the yeast or yeast & sugar solutions?
2. Which solution appears to have more yeast cells?
3. How do yeast cells reproduce (method)?
4. Why are there more cells in tube (_____) than in tube (_____)?
5. What variable is used in this experiment?

Interpretation of Data

Does yeast live and reproduce by using sugar as food?

FOOD FOR YEAST (3 kinds of sugar)

Problem
Does yeast ferment other kinds of sugars?

Background Information
The sugar used for the past experiment was cane sugar or sucrose that we commonly use to sweeten coffee, tea, milk or cereals

Glucose is a simple sugar found in plants or fruit
Dextrose is a sugar of the blood
Lactose is a sugar of milk

Sucrose - $C_{12}H_{22}O_{11}$

Glucose - $C_6H_{12}O_6$

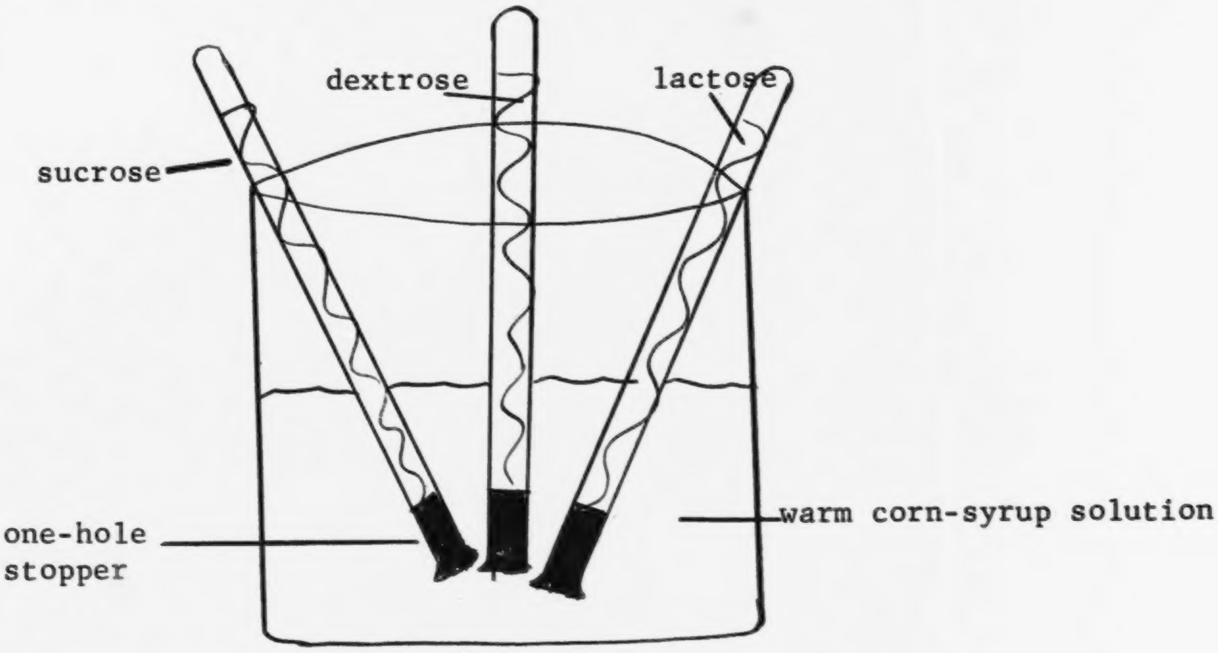
Hypothesis

Design for Collection of Data

Use three sugar solutions: sucrose, dextrose and lactose and add yeast

Place these with yeast in test tubes and invert test tubes with one-hole stoppers into a corn-syrup solution.

Gas will force the mixture from each tube, thus you are able to tell the rate of fermentation by the amount left.



Procedure (draw diagrams for all observations)

1. Make 3 test tubes X, Y, Z
2. Pour ½ vile capful of yeast in all tubes
3. Pour in 9/10 tubeful (¼" from top of tube) of
   glucose in tube X
   dextrose in tube Y
   lactose in tube Z
4. Obtain a beaker of warm corn syrup and place all three tubes upside down in the beaker.
5. Wait for 10 minutes and observe the amount of gas in each tube.

Observations

1. Which sugar does yeast react with more quickly?
2. Which sugar does yeast ferment easily?
3. Which mixture gives off more gas?
4. In what order of sugars does yeast react? (strongest to weakest)

Interpretation of Data

1. Does yeast ferment other sugars?
2. Does fruit contain sugar?
3. What kind of sugar do you find in blood?
4. What kind of sugar do you expect to find in milk?
5. What kind of sugar would you find in sugar cane or in sugar beets?

PRODUCTS OF YEAST AND SUGAR

Problem

Does yeast & sugar produce alcohol?

Background Information (Alcohol)

Making Wine

There are many activities in which yeast is important. For instance it is used in the brewing of beer and in the making of various wines.

Most kinds of fruit, but particularly grapes have yeast cells growing on their skins. When grapes are crushed to make wine, the yeast from their skins acts on the sugar they contain, to make alcohol.

Design for Collection of Data (use a juice from some fruit and add yeast)

Procedure Stage 1 (draw diagrams for all observations)

1. Sprinkle a few grains of dried yeast into a test tube of apple juice and label it tube #1.
2. To another tube, add plain apple juice, label it #2.
3. To a third tube, add a plain yeast solution - label it #3.
4. Label the test tubes with your station number and your grade letter.
5. Plug the tubes with a ball of cotton.
6. Set the tubes in a warm place and leave for a few days

Observations (after a few days)

1. What is the color of the apple juice?
2. What is the color of the apple juice & yeast?
3. What is the color of the plain yeast solution?
4. Which tube appears to be cloudier?
5. Which tube has the stronger smell?
6. Which tube tastes sweeter?

Procedure Stage 2 (draw diagrams for all observations)

1. Fill three test tubes ¼ full with potassium permanganate solution. Label them as #1, #2, and #3.
2. Add an equal amount of apple juice to #1 as to amount of permanganate solution.
3. Add an equal amount of apple juice & yeast to #2, as to amount of permanganate solution.
4. Add an equal amount of plain yeast solution to #3.
5. Heat all tubes till they bubble.

Observations

A. Apple Juice

1. What is the color of potassium permanganate?
2. What color did it change to when heated with apple juice?
3. Was a deep brown residue left?
4. Does apple juice contain alcohol?

B. Plain Yeast Solution

1. What color did the permanganate solution change to?
2. Was a deep brown residue left?
3. Does plain yeast contain alcohol?

C. Yeast & Apple Juice

1. What color did the permanganate solution change to?
2. Was a deep brown residue left?
3. Does the yeast & sugar (apple juice) solution contain alcohol?

Interpretation of Data

What product does yeast & sugar produce?

PRODUCTS OF YEAST AND SUGAR

Problem
What is the gas given off when yeast and sugar react?

Background Information
The reaction of yeast with sugar is called fermentation. In fermenting, yeast breaks down the sugar for food energy and releases some waste products in the process. These waste products are what we will test for.

Hypothesis
(given) that yeast is a plant
sugar is a chemical with carbon atoms
hydrogen atoms
oxygen atoms
What possible gases could be given off?

Design for Collection of Data

1. Prepare 1 test tube (A) of yeast solution as control.
2. Prepare 1 test tube (B) of yeast & sugar solution as experimental.
3. Cover with balloons.
4. Heat test tubes A and B. Test for carbon dioxide.

Procedure Stage 1 (draw diagrams for all observations)

1. Heat test tubes A and B from above in a hot water bath for 4 minutes.
2. Let solution cool for 5 minutes. Observe balloons A and B.

Observations Stage 2

1. Which balloon filled first (a) from yeast solution or (b) yeast & sugar solution?

2. Which balloon has more gas in it?

3. Which solution reacted the most?

Procedure Stage 3 (draw diagrams for all observations)

1. Mark two test tubes A_2 and B_2.
2. Fill each, half full of limewater.
3. Pinch the balloon from the yeast solution at the top of the tube to hold in the gas.
4. Remove balloon from tube A, place on tube A_2 without losing the gas.
5. Remove balloon from tube B, place on tube B_2.
6. Shake both well.

Observations Stage 3

1. What color is limewater?
2. What color is the limewater after the gases enter the tube?

Interpretation of Data

1. What is the gas given off during fermentation?
2. List some ways this gas is useful to man?

PRODUCTS OF YEAST AND SUGAR

Background Information (carbon dioxide)

Making Bread

Yeast lives in places where a supply of sugar is available. Normally the gas formed by a fungus escapes into the atmosphere, but for many centuries man has made use of it in making bread.

When the dough is made with flour, sugar and water; yeast is added to raise the dough.

In a past experiment, the balloons of two control tubes "C" and "D" did not inflate as much as tube "B". This showed that yeast or sugar alone will not produce the gas given off by the reaction of yeast with sugar.

Has this got anything to do with the reason we use yeast in making bread?

Try making some dough and find out (directions on page 8, Test II, text book)

SET B: MOLDS

Problem

Does mold contain chlorophyll?

(a) bread mold

(b) fruit mold

Hypothesis

Design for Collection of Data

Use ¼ test tubeful of alcohol and mix (a) bread mold
(b) orange mold

Procedure (draw diagrams for all observations)

Observations

A. Of Bread Mold

1. What is the color of bread mold?
2. What is the color of chlorophyll?
3. Is the mold the same color as chlorophyll?

B. Of the Alcohol from Bread Mold

1. What color does the alcohol turn to?
2. Is this the color of chlorophyll?

Observations

A. Of the Orange Mold

1. What is the color of orange mold?
2. Is this the same color as chlorophyll?

B. Of the Alcohol from the Orange Mold

1. What color does the alcohol turn to?
2. Is this the color of chlorophyll?

Interpretation of Data

Results

Does mold contain chlorophyll?

Questions

1. Does mold make its own food?
2. Yeasts, molds, and bacteria belong to the subphyllum called: ____________.
3. What foods do you think molds use to live on and multiply?

Diagram

Change of alcohol before and after using (1) bread mold
(2) orange mold

FOOD FOR MOLDS

Problem
How fungus plants obtain their food, namely mold.

Hypothesis

Design for Collection of Data

Use two containers, both with a portion of bread in them Moisten one piece of bread with no more than 10 drops of water. Seal or cover both pieces of bread and keep in a dark, cool room.

Procedure (draw diagrams for all observations)

Observation (in next class of both pieces)

Observation (after 1 month)
a) in petri dish

b) in baggie

Interpretation of Data

1. Where did the mold come from?

2. What condition varied in the experiment (variable) in trying to grow mold?

3. What is the food nutrient present in bread?

WHAT MAKES BREAD GET MOLDY

When bread is several days old, you sometimes find little patches of green or gray mold on it. The mold is really a patch of tiny, tiny plants, which grow like weeds in a garden.

Weeds grow wild. Nobody plants them in a garden. Nobody plants mold either. Where does mold come from? It comes from little specks that float around in the air - specks so small that you can't see them. When the specks land on a piece of moist bread in a warm room, they begin to grow, just as seeds grow in warm, moist soil. The tiny plants are shaped like flowers, but they are not really flowers. When they have grown, they send out more little specks into the air and onto the bread. The specks are called spores and they are like seeds.

Sometimes mold spores fall onto very dry bread in a very dry room. Then they can't grow. They need moisture, just as all plants do.

Mold grows on other things beside bread. It grows on meat and on vegetables stored in damp places. It grows on the top of home-canned foods that haven't been closed up tight. It can even grow on shoes and clothes and books in damp closets.

MOLDS

A diagram showing a typical bread mold (RHIZOPUS) will be provided.

After doing some library research, label the diagram.

Draw a small portion of mold provided in class on a bioscope. Label the parts you observe and pay particular attention to individual spores or cells.

MICROBIOLOGY TECHNIQUES (demonstration)

1. Microorganisms - microscopic - plant
   - animal

2. Culture - pure culture
   - mixed culture
   - contaminated culture

3. Culture Medium (nutrients or food for growth of a culture)

4. Equipment to grow cultures
   - petri dish
   - flask
   - test tubes

5. Innoculating (pure cultures)
   - equipment - loop
     - needles
     - swab
     - glass rod

6. Sterilization (the complete removal or destruction of all living forms of microorganisms)

   A. Heat (1) heat under pressure (autoclave or pressure cooker)
   (2) direct flame

   B. Chemicals - disinfectants or germicides
   - antiseptics
   - antibiotics

   The above methods used to prevent excess of microorganisms is known as aseptic techniques.

Disinfectant - a chemical substance which kills bacteria or any other microorganism (used on glassware or other equipment, e.g., Lister used carbolic acid to sterilize his operating room)

Antiseptic - a chemical which prevents, stops, or inhibits growth. Used on living tissues such as skin, mouth, throat.

Antiobiotic - a chemical produced by an organism that inhibits growth of microorganisms.
Used: taken internally by mouth or needle

FOOD FOR MOLDS

Problem

What foods are most suitable for mold growth.

Background Information

In the next labs you will investigate what types of food molds grow on.

Common Foods are Generally Classified as Follows:

Proteins

Proteins are the chief constituents (other than water) of the lean tissues of the body, such as muscles and blood. The body requires proteins in the diet for growth, and to replace its own protein stores, which are continually being depleted. The processes of digestion break down proteins into simpler units called amino acids, which are then reassembled into other proteins in the tissues.

Ten of the many different kinds of amino acids are essential to life, and must be furnished by protein in the diet. Proteins differ in their content of these essential amino acids. In general, animal proteins such as meats and milk are of better biological value than plant proteins. However, a diet containing both plant and animal protein is both nutritionally and economically desirable.

Protein sources (arranged in descending order of nutritive value) include: whole egg, milk and cheese, meats, fish and poultry, rolled oats, whole wheat, corn meal and white flour.

Carbohydrates

The carbohydrates include two large groups of closely related substances, sugars and starches, which are built up from simple sugars. Carbohydrates are used primarily for energy, either for internal or external work, or for heat. The may also be stored as glycogen (muscle starch) or converted into body fat.

Carbohydrates represent the most economical sources of body energy; as such they are the foundation of any diet. Continued use of diets too high in sugar may produce cavities in the teeth or accentuate diabetic tendencies.

The principal sources of carbohydrates are cereals, such as bread and other bakery goods, breakfast cereals, most vegetables, dried legumes, dried fruits, bananas, sugar, jellies and jams, candies and honey.

Fats

Fats are mainly a source of energy, and are more than twice as effective in this respect as carbohydrates. Many fats carry important amounts of the fat-soluble vitamins A, D, E, and K. Certain "unsaturated" fats (soft fats and oils) contain unsaturated fatty acids believed essential for proper nutrition. Body fats furnish energy reserves (although too much body fat may tend to shorten life). Fat in cookery makes food seem more appetizing and, by delaying the emptying time of the stomach, makes a meal seem to "stick to the ribs". Dietary fats aid in the absorption of the fat-soluble viatmins and perhaps calcium.

Essential unsaturated acids are found in butter, cod-liver oil, lard and various vegetable oils, such as corn-germ, cottonseed, olive, peanut and soybean oils.

The best food source of fats are fat meats, butter, fortified margarine, cream, most cheezes, edible oils, lard, shortenings, most salad dressings, egg yolks, nuts, and soybeans.

Two samples of each classification of foods will be used to observe mold growth.

FOOD FOR MOLDS

Prediction

Design for Collection of Data

Using samples of food from each class, test pure cultures of mold.

Procedure: Stage 1 (draw diagrams for all observations)

1. Fill test tubes with foods to be tested using techniques given in diagram.
2. Plug test tubes with cotton.
3. Sterilize test tubes and food by heating in a pressure cooker for 20 minutes.
4. Remove cotton plug and place mold on the food.
5. Let tubes stand in moderate light for a few days and compare tubes.

Observations

1. On what foods do you find rhizopus most plentiful?
2. On what foods do you find penicillium most plentiful?
3. What is the class of foods most suitable, for both molds?
4. Did all the tubes contain a pure culture of mold?
5. Suggest why they may not be pure cultures.
6. If all the rhizopus mold was destroyed by bacteria
   (a) Criticize this statement: ____________________ is the most suitable food for molds.

   (b) Why were two kinds of mold used?
7. How may this experiment be improved?
8. What color indicated bacteria?
9. From past experiences, we observed that mold can grow on other foods such as proteins and fats. Suggest reasons why there was little on other food.

Interpretation of Data

Conclusion

What class of food is most suitable for mold growth?

MOLDS: CONDITIONS FOR GROWTH (HEAT)

Problem

How does varying amounts of heat affect mold growth?

Prediction

Design for Collection of Data

Group 2 will use 9 test tubes, some as control and some experimental.

Amounts of heat will be: about 100°
room temperature
freezing (32°)

Procedure

(draw diagrams for all observations)

(In writing your procedure keep in mind which tubes are control and which are experimental.)

Observations

1. What was your control temperature?

2. Why did you pick this as a control?

3. You observed all the tubes in a few days after innoculation.
   (a) Was the amount of mold growth in each tube about the same?

   (b) Suggest why the amount of mold might not be the same in each tube?

4. At which temperature did the molds seem healthier?

5. Describe the condition of molds placed at the other two temperatures.

6. If the control tubes at one temperature were placed in a lighted room and the experimental tubes kept in the dark:

   (a) What is the new variable entered?

   (b) Could you tell which variable affected growth (temperature or light?)

   (c) How might this affect the experiment?

7. Did every tube contain a pure culture?

8. Suggest four reasons why you may not have a pure culture.

   (a)

   (b)

   (c)

   (d)

Interpretation of Data

Conclusion

How does varying heat affect mold growth - over 100°
- room temperature
- freezing

MOLDS: CONDITIONS FOR GROWTH (LIGHT)

Problem

How does varying amount of light affect mold growth?

Prediction

Design for Collection of Data

Group 1 will use nine test tubes, some as control and some experimental.

Amounts of light will be: dark room
moderate light (amount of light in a classroom)
direct light

In each tube penicillium mold will be inoculated into a piece of potato

Procedure (draw diagrams for all observations)

(In writing your procedure keep in mind which tubes are control and which are experimental.)

Observations

1. What was your control amount of light?

2. Why did you pick this as a control?

3. You observed all tubes in a few days after inoculation:
   (a) Was the amount of mold growth in each tube about the same?

   (b) Suggest why the amount of mold might not be the same in each tube.

4. At what amount of light did the molds seem healthier?

5. Describe the condition of the mold placed at the other two amounts of light.

6. If the control tubes at one type of light were placed in a heated room and the experimental tubes were placed in a cool room:
   (a) What is the new variable entered?

   (b) How might this affect the experiment?

   (c) Could you tell which variable affected growth (light or temperature)?

7. Did every tube contain a pure culture?

8. Suggest four reasons why you may not have a pure culture?

Interpretation of Data

Conclusion

How does varying amounts of light affect mold growth?

(a) direct light

(b) moderate light

(c) dark (no light)

MOLDS

Project

You will attempt to grow three different kinds of mold on bread. They are:

Aspergillus (a greenish blue mold)
Rhizopus (a black mold)
Penicillium (a green mold)

You will be given three weeks to grow these specimens and a mark will be given according to how well you follow instructions.

Instructions

Aspergillus

Expose bread to air for several hours till quite dry. Then soak in a sugar solution (sucrose), grape juice and prune juice. Then seal and keep in a dark place.

Rhizpous

Wipe a slice of bread on a dusty surface and sprinkle lightly with water and place in a sealed jar. Keep in moderate light. Home-made bread is better.

Penicillium

Same as above only keep in a dark room. This mold may take longer to grow. You may transplant some species from an orange as this is also penicillium.

Assignment: Uses of molds to man

The report should be at least two pages long, along with diagrams. Diagrams will consist of what the mold looks like under a microscope. In reporting you should include where you'd most likely find these kinds of molds growing. A mark will also be allotted for this report.

Set C: BACTERIA (LOUIS PASTEUR EXPERIMENT)

Problem

Is bacteria found in the air?

Background Information

In the eighteenth century people still thought that microbes (little animals) appeared mysteriously from materials such as mud, which is not alive. This idea is known as the "theory of spontaneous generation" - suggesting that living things could suddenly be formed from non-living things.

A scientist beyond his time, Spallanzani, tried to prove that liquids containing bacteria were boiled and sealed off, no microorganisms would be found. Thus he concluded that tiny living things could not be formed from something which is not living. However, few people believed him as he lacked controls in his experiment.

It was not until 1861, that the famous French scientist Louis Pasteur carried out a series of experiments to find out if bacteria could be formed from dead material in presence of air.

The following is a modified experiment of Louis Pasteur. Read Chapter 1, Book 2.

Hypothesis

Design for Collection of Data

Procedure (use text book as a guide, draw diagrams)

Observations	Day 3	Day 5	Day 7
Test Tube 1			
Test Tube 2			
Test Tube 3			
Test Tube 4			
Test Tube 5			

BACTERIA: (WHERE ARE BACTERIA FOUND)

Observations

1. Which tubes remained clear?
2. Did the fact that the broth in test tube #1 was not sterilized have any effect on the speed with which the broth went turbid?
3. The broth in test tube #2 was sterilized. If it went turbid, why was this so?
4. (a) What were your results in tubes #3 and #5?

   (b) Did you obtain the same results in both? If so, explain why?
5. What was the purpose of the "S" shape in the flask used by Pasteur?
6. What were the results in test tube #4?
7. Did tube #4 act as a control for tube #5? Explain.
8. Why did Pasteur's experiment succeed in disproving the theory of "spontaneous generation"? P. 14, Book 2.

Interpretation of Data

Conclusion

BACTERIA (WHERE ARE BACTERIA FOUND?)

Problem

Where is bacteria found?

Hypothesis

Design for Collection of Data

Using petri dishes filled with nutrient agar (sterilized by teacher), test different specimens for bacteria using aseptic techniques.

Test 1: 1) control
2) open dish in classroom
3) cough into dish and close
4) unwashed fingers
5) milk
6) water

Incubate at 98°F (37°C)

Procedure

(draw diagrams for all observations)

Observations

Draw the 6 dishes showing the amount and pattern of bacterial growth.

Interpretation of Data

Conclusion

WHERE ARE BACTERIA FOUND?

Problem

Does washing affect the number of bacteria?

Background Information

Before having a meal, we are taught to wash our hands. If you have been cleaning, bicycle riding, or playing football, your hands may look dirty. But, are bacteria on our hands, and are there more bacteria on unwashed than on washed hands?

Read p. 21, Book 2, Nuffield Biology

Prediction

Design for Collection of Data

Petri dishes of nutrient agar will be used to test amount of bacteria from:

(a) unwashed hands
(b) hands washed for 1 minute
(c) hands washed for 2 minutes
(d) hands washed for 3 minutes
(e) hands washed for 4 minutes
(f) hands washed for 5 minutes

Observations

1. (a) Have any bacteria grown on the control?

   (b) What does this tell you as far as other variables entering into the experiment?

2. Which had more growth?

   unwashed or washed for 1 minute
   unwashed or washed for 2 minutes
   unwashed or washed for 3 minutes
   unwashed or washed for 4 minutes
   unwashed or washed for 5 minutes

3. Which dish gives maximum amount of growth?

4. How long should you wash your hands before bacterial growth becomes less and less?

5. Why does growth increase with washed hands for 1 minute, 2 minutes and 3 minutes?

Observations

By dividing your petri dish with a marking pencil into quarters or even into eight equal parts, approximate the percentage of area covered by bacteria in each part.

Then total these and average the percentage found in the whole dish.

Percentages found in parts: (a) (e)

(b) (f)

(c) (g)

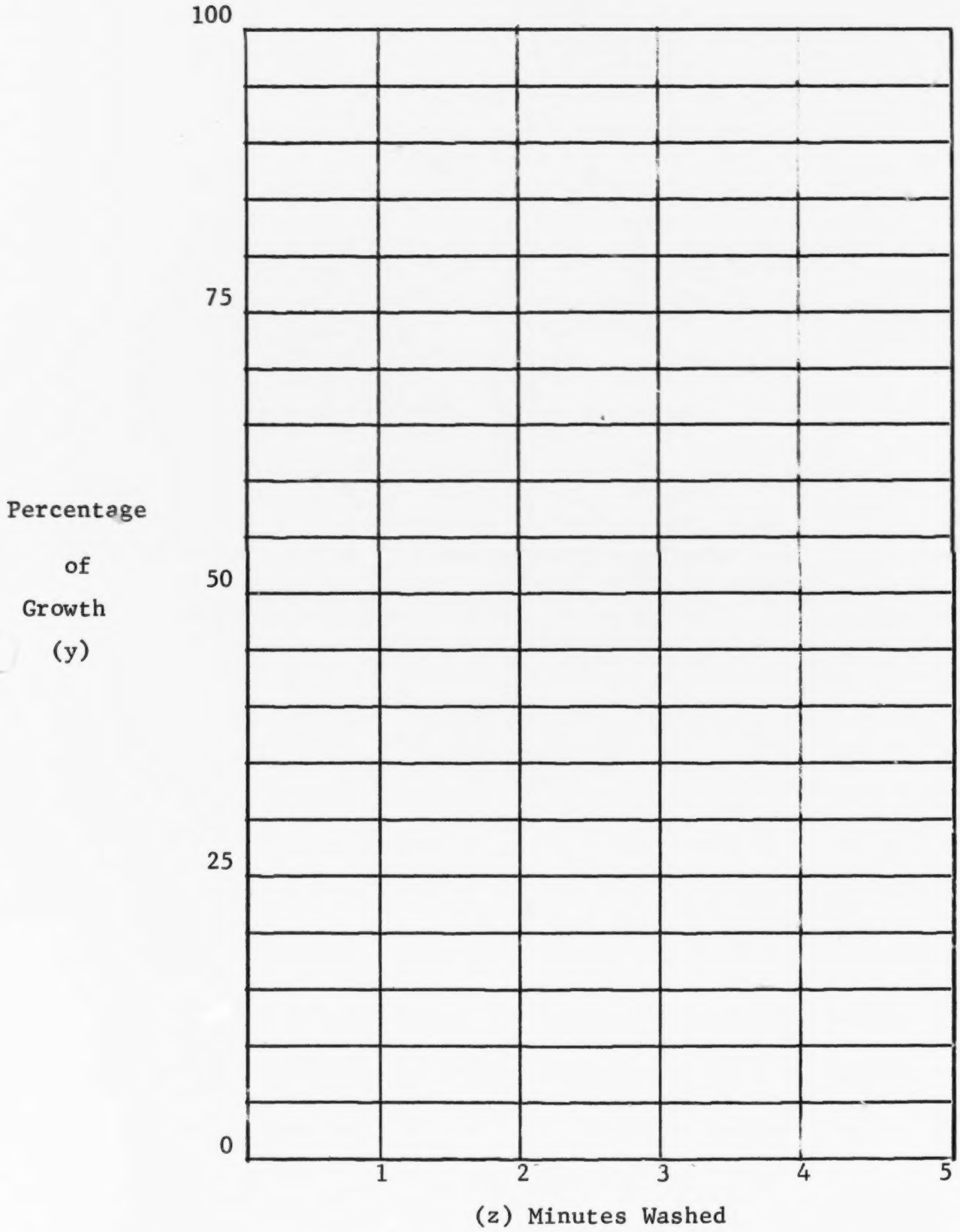
(d) (h)

Total percentage = ________

Draw a graph using the "x" variable as time hands were washed (in minutes) and the "y" variable, the amount of bacteria in each plate (%).

Plot the points and join all of them with a curved line.

WHERE ARE BACTERIA FOUND



1. Washing hands for _____ minutes gives the greatest amount of bacterial growth.
2. At what time do you find the least amount of growth? _____
3. What is the percentage growth: (a) at 2½ minutes _____, (b) at 3½ minutes? _____ (c) at 4½ minutes? _____
4. By extending your graph, what do you expect the percentage at 6 minutes? _____
5. What advantage do you see in plotting a graph to show your results?

BACTERIA: CONDITIONS FOR GROWTH (HEAT)

Problem

How do varying amounts of heat affect bacterial growth?

Prediction

Design for Collection of Data

Group 2: Leave Petri dishes of nutrient agar (sterilized) open in the auditorium for at least 12 hours to obtain bacterial growth. Seal these dishes and then subject to varying amounts of heat.

a) low heat (freezing - 32°)
b) moderate heat (room temperature)
c) high heat (incubator 98°)

Procedure (draw diagrams for all observations)

In writing your procedure, first indicate how many dishes are used for control and experimental. Indicate which condition of light is used as control.

Observations

1. Draw diagrams to show growth in each dish.
2. What was the purpose of leaving all the sterilized dishes open?
3. Why were dishes set in another room other than where we previously worked with molds?
4. Which temperature did you use as your control?
5. Why did you use this temperature as your control?
6. Which temperature seems to provide a better growth?
7. Which temperature provides the least growth?
8. What other evidence can you give to support your experiment as to what temperature is best for growth of bacteria?

BACTERIA: CONDITIONS FOR GROWTH (LIGHT)

Problem

How do varying amounts of light affect bacterial growth?

Prediction

Design for Collection of Data

Group 1: Leave Petri dishes of nutrient agar (sterilized) open in the auditorium for at least 12 hours to obtain bacterial growth. Seal these dishes and then subject them to varying amounts of light:

a) no light (dark)
b) moderate light
c) direct light

Procedure (draw diagrams for all observations)

(In writing your procedure, first indicate how many dishes or areas of the dishes are used for control and experimental. Indicate which condition of light is used as control.)

Observations (draw diagrams to show growth in each dish)

1. Why were all the dishes left in the same area of a room?

2. By placing them in different areas, what new variables enter the experiment?

3. (a) Which amount of light did you pick as your control?

   (b) Why?

4. Which amount of light provides:
   (a) the most growth

   (b) the least growth

Interpretation of Data

Conclusion

WAR ON BACTERIA

Problem

What is the effect of antiseptics on bacterial growth?

Background Information

From previous experiments and research, we have found bacteria present almost everywhere; in the air, in water, and in the soil. There are helpful and harmful bacteria. Man has been especially concerned about harmful bacteria growing within the human body that cause numerous diseases.

Prediction

Design for Collection of Data

Using dishes of sterilized nutrient agar:
(a) to one dish, add enough water to cover half of the agar (control)
(b) in all other dishes add enough water to cover half of the agar plus a few drops of an antiseptic to be tested.

Procedure (draw diagrams for all observations)

Observations

1. Why was water used in all the dishes?
2. (a) Why didn't we use throat swabs from different people on each dish instead of water?

   (b) What other new variables would be involved if throat swabs were used?
3. Why did you use a dish without any water or antiseptic?
4. In which dishes did you find growth?

scope & water

listerine & water

hydrogen peroxide & water

colgate 100 & water

mercurochrome & water

micrin & water

plain tap water

Interpretation of Data

Conclusion (answer the original problem)

WAR ON BACTERIA

Problem

What is the effect of antibiotics on bacterial growth?

Background Information

What is the effect of antibiotics on bacterial growth?

Prediction

Design for Collection of Data

Using dishes of sterilized nutrient agar: inoculate dishes with a throat swab and place two antibiotic discs at one inch from the edge of dish.

Procedure (draw diagrams for all observations)

Observations

Draw a diagram showing amount of bacterial growth in each dish.

1. Do the colonies come up to the edge of both the antibiotic discs or is there a clear ring where bacteria has not grown? If so, offer an explanation.
2. Is there a larger ring around one disc than the other? Which one?
3. Can you give a reason for one disc to have a larger ring than another?
4. Using a ruler, measure in millimeters, the diameter of the ring and the diameter of the disc. Subtract the diameter of the disc from that of the ring and find out the area. $A = \pi r^2$

REVIEW AND QUESTIONS

Fungi

1. Suppose you are sent to collect various fungi for a class demonstration. Where would you look for: (be specific)

    (a) yeast

    (b) molds

    (c) bacteria

2. What is the structure of mold that allows it to adapt to harsh climatic changes.

3. What factor gives bacteria a wider distribution than the other types of fungi?

4. What are the economic and social consequences of diseases caused by fungi in Canada?

5. What are some of the ways in which fungi are important to our daily lives?

6. What are some measures to prevent fungus growth, namely:

    molds

    wheat rust

    smut

    bacteria

7. What evidence is there that fungus is a living thing?

8. What evidence of life processes do you find in both animals and fungi?

MICROBIOLOGY: STUDENT'S NOTES

THE USE AND CARE OF A MICROSCOPE

I. Types of Microscopes

1. Blister
2. Bushnell — Monocular (2 lens system with one ocular lens)
3. Microprojector
4. Bioscope (stereoscope) — Binocular (2 lens system with two ocular lens)

II. Identifying the Parts of a Microscope

(Refer to a microscope or to the diagram on p.2)

The microscope stands on a Base, which is attached to an Arm. The arm supports the Body Tube or ocular tube, which connects the systems of lenses. At the top of the tube is the Eyepiece or Ocular Lens into which you look. The eyepiece forms a separate unit which provides a magnification of about 10 times. Attached to a Revolving Nosepiece at the bottom of the tube, are the three objective lenses. Each of these contains another lens system. The Low Power Objective (the shorter one) magnifies about 4 times, Middle Power Objective magnifies 10 times, the High Power Objective (the longer one), magnifies about 40 times. The nosepiece can be revolved until one of the objectives clicks into place in line with the body tube and the eyepiece.

The magnifying power of a microscope is determined by multiplying the power of the eyepiece and that of the objective lens. For example, if the power of the objective lens is 40x (called "40 power") and that of the ocular lens is 10x, then the power of the combination is 40 times 10, or 400. This means that the diameter of the object you see is enlarged 400 times. Therefore, by swinging different objectives into place, different magnifications are obtained.

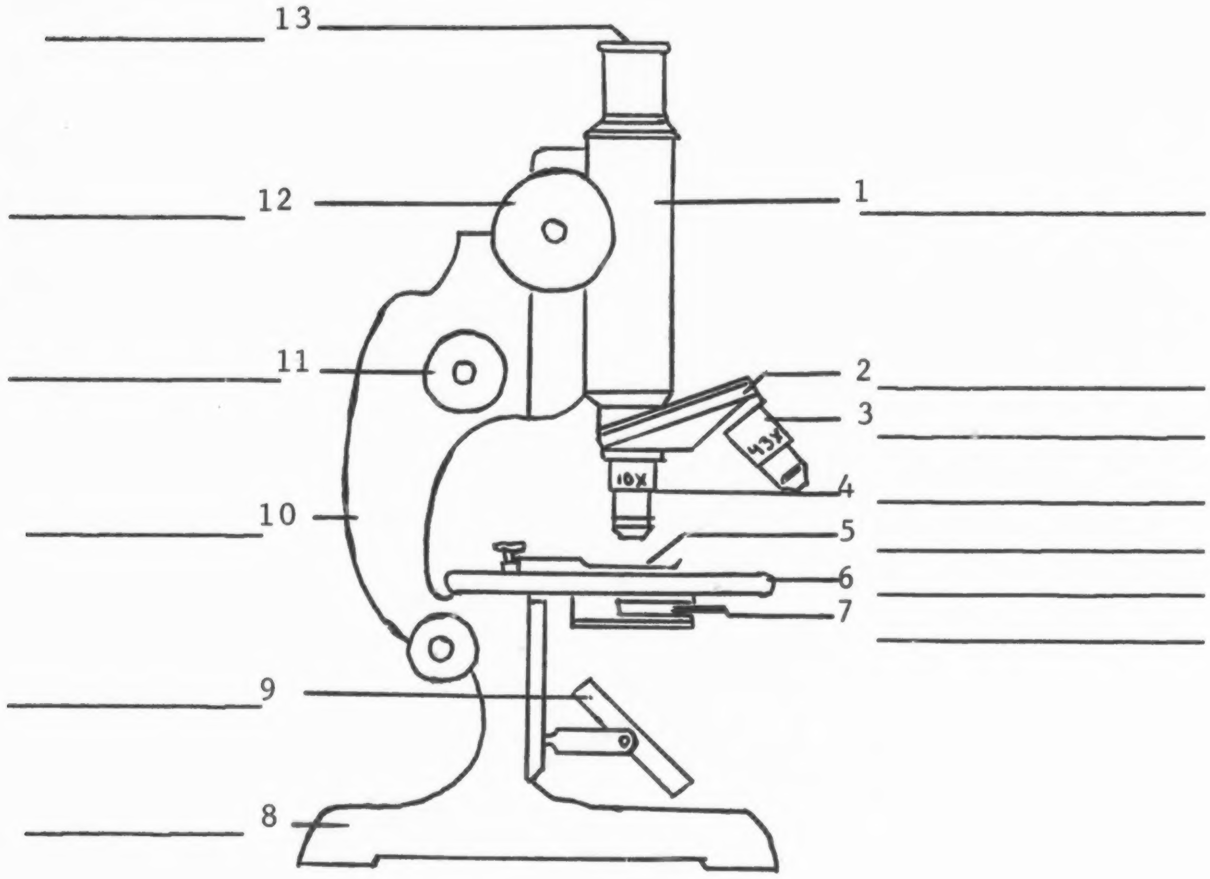
The object being studied is placed on a slide, which is held over the opening in the centre of the Stage by means of two clips. The Plane-Concave Mirror beneath the stage directs light through the hole, the object and the lens systems of the body tube to the eye. Sometimes a Substage Condenser is mounted beneath the stage. This is a system of lenses designed to focus light on the subject. Sometimes a Diaphragm also lies beneath the stage. Its function is to control the light intensity at the object. If there is no condenser, use the concave side of the mirror; this concentrates the light. When the microscope has a condenser the plane mirror is used with it. Some microscopes have direct substage lighting.

The mirror can be moved in both a horizontal and vertical plane. When you rely upon the mirror you must work where there is adequate lighting or use a portable table lamp. Make sure the light falls on the mirror not on the stage. Keep the mirror properly adjusted all the time. It must be set so that it picks up the light from its source and reflects it to the specimen under examination. Before you begin work, adjust the mirror so that the field is illuminated evenly and brightly. If you move the microscope after making this adjustment, the mirror will have to be adjusted again.

Focussing is accomplished by means of an Adjustment Screw, mounted on the arm which either moves the body tube or the stage. Always start with the low objective when focussing and gradually work up to the higher power objective. Some microscopes are focussed by means of Coarse and Fine Adjustment Screws. The coarse adjustment is used with the low power objective or when using the high power objective for focussing the tube upward (away from the stage). For picking out fine detail, the fine adjustment is used with the high power objective. Careless use of the coarse adjustment is liable to drive the objective into the object, destroying the slide (object) and the lens.

Become familiar with the movement of the adjustment screws.

Before rotating the nosepiece to change to a high-powered objective, make sure there is no danger of the objective lens hitting the slide.



- write the name of each part beside the corresponding number

HOW TO USE HAND LENS

1. Hold lens to eye (½" or 1") and hold stationary.
2. Move specimen up to hand lens to focus.
3. Keep both eyes open.

ADJUSTING YOUR MICROSCOPE

1. Arrange the mirror to reflect the light towards the stage.
2. Place your slide on the stage with the specimen near the centre of the hole.
3. Select the objective with lowest power - the one with the shortest mount and the widest lens.
4. Look at the side of the microscope and turn the coarse focussing knob to bring the objective as close to the slide as you can without the two touching. (Remember that in some microscopes the focussing knob moves the tube, and in others the stage.)
5. Look through the eyepiece and turn the focussing knob to move the lens away from the slide. NEVER FOCUS BY MOVING THE LENS TOWARDS THE SLIDE WHILE LOOKING THROUGH THE EYEPIECE.

If you do move the lens and slide towards each other and miss the focus point, you are likely to crush the slide and lens when they meet. This can be an expensive mistake! But if you miss the focus while you are moving the slide and lens away from each other, you will merely reach a point at which the tube will travel no further. Do not try to force the knob beyond this point. Start again by bringing objective and slide close together and then move them apart a little more slowly and look more carefully. You should eventually reach a point where you see a clear picture through the eyepiece. Try to keep both eyes open while you look down the instrument.

6. At this stage check on the lighting by removing the eyepiece and looking down the tube at the back of the object lens. This should be evenly illuminated and should be three-quarters filled with light. If you cannot get this right by moving the mirror, ask for help. Unless the lighting is correct you will not get the best results. Keep the eyepiece in your hand or in a safe place and not on its side where it can roll.

7. Now replace the eyepiece and examine a slide of a specimen. When you try to move the slide to a new part you will find another difference between the hand lens and the compound microscope. The object and image move in opposite directions. This you will have to get used to.

Exercises with the Microscope

A.

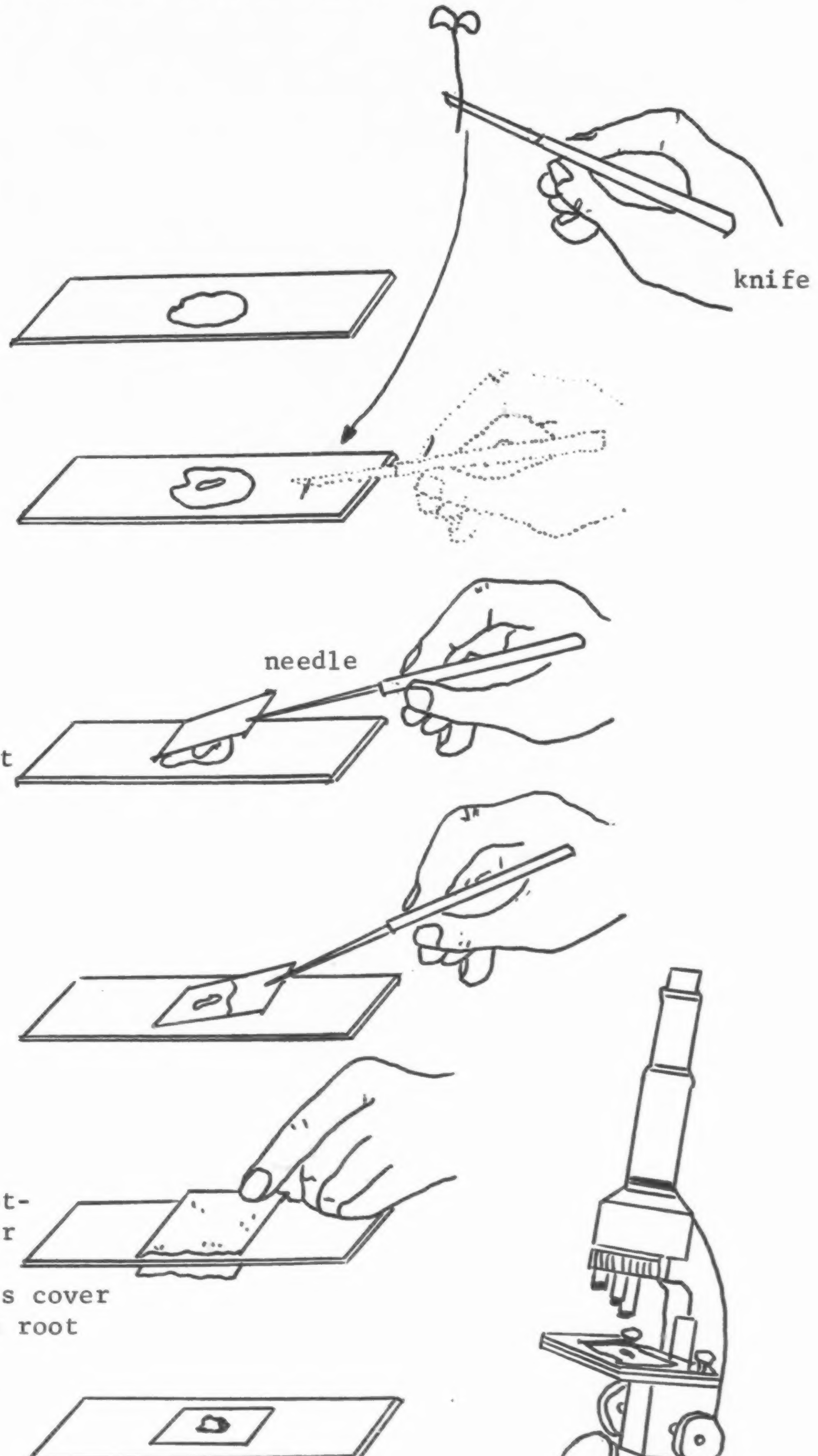
1. Cut out the typed letter (e) from the bottom of this page.
2. Place the word on a slide and observe with the microscope. Use the low power objective. Place the slide on the stage with the object (the word) directly over the opening of the stage.
3. If the low power objective is placed about 1/8" above the stage, the object will be out of focus. Slowly and carefully turn the coarse adjustment screw to move the body tube up until the letter comes into focus. If the microscope has a fine adjustment, use it for finer focussing.
4. When this is done, turn the nosepiece so that the medium power objective is in place. (Note: do not use high power objective at this point.)
5. Briefly describe what you see.

B.

1. Cut out the letter e from your word and place it on the slide again. If the letter is placed in a drop of water on the slide there is less chance of it being blown off the slide.
2. Observe the letter under the microscope using the low power objective.
3. Then slowly move the slide (a) to the left
   (b) to the right
   (c) away from you on the stage
   (d) toward you on the stage
4. Briefly describe what happens.

e e e e e e e e e e e e e e e e e e e e

INTRODUCING LIVING THINGS



1. slide with drop of water
2. transfer ¼ inch of root tip to slide
3. touch cover glass on water and support by needle
4. lower cover glass on to root and water
5. wrap a piece of blotting paper or filter paper round the slide and then press cover glass to squash the root
6. transfer slide to microscope

Figure 42
Stages in making a preparation of mustard root.

Reproduced from Nuffield Text I.

C.

1. Examine a very thin piece of cork and a small piece of cloth or nylon under the microscope using the low power objective. A drop of water or glycerine will keep the object in place on the slide.
2. By varying the attachments on the microscope at different settings briefly describe with diagrams the effect these settings have on seeing the object.

VI. Mounting Specimens for Microscopic Examination

1. Before using a microscope slide or a coverslip, they should be washed off and dried making sure they are perfectly clean. They are fragile and expensive and should be cleaned carefully.

2. Specimens seldom, if ever, are examined in the dry state but are mounted in a fluid for examination. Whatever the mounting fluid used, care should be taken to use an amount just sufficient to fill the space between the coverslip and extend to the edge of the coverslip. If too much fluid has been used then the excess can be soaked up with small pieces of paper towelling, placed by the edge of the coverslip.

A. Stages in Making a Temporary Slide

1. Using a medicine dropper, place one or two large drops of water on the glass slide.

2. Now place your specimen (a piece of course cloth) in the water.

3. If you are right-handed, place the coverslip obliquely on the left side of the water. Hold the right edge of the coverslip until a needle can be placed under the coverslip so it can be lowered slowly.

4. The coverslip is then slowly lowered driving all the excess air bubbles out surrounding the specimen. This is done to avoid the presence of air bubbles in the area surrounding the object.

5. Patiently lowering this coverslip will be rewarded by having an excellent mounted specimen.

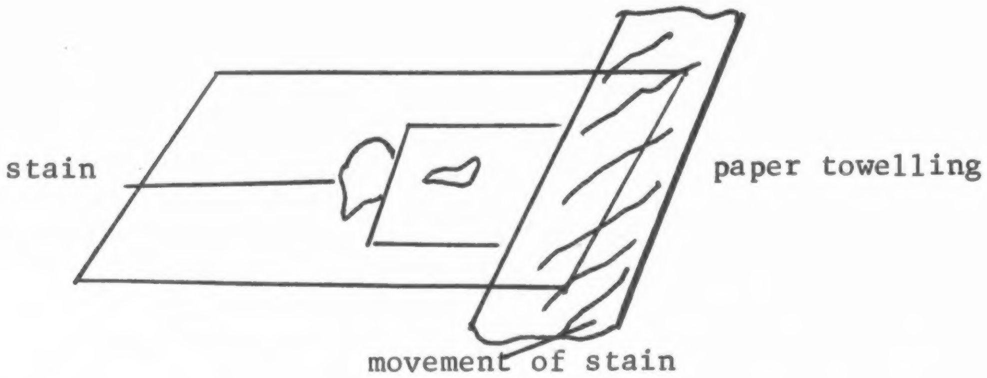
6. Draw off any excess water along the coverslip edges using a piece of paper towelling. Specimen can be stained at this point using the flow technique. (Refer to staining.)

7. To keep your specimen from drying out a coat of nail polish could be applied around the edges of the coverslip. Or else, a drop of water around one of the edges will replace the water evaporated.

B. Staining

(a) Total immersion -- this involves immersing the specimen in a series of dies or stains depending on the desired effect (e.g., iodine solution, ink solution)

(b) Flow technique -- this allows the stain to creep underneath the coverslip staining the specimen as the stain is drawn through.
Place a paper towelling at one edge of the coverslip and at the same time add a drop of the desired stain at the opposite side of the coverslip. When the paper absorbs the water from underneath the slide the stain replaces the water.



C. Assignment

1. Make a temporary slide of a small piece of cloth or nylon material stained with iodine solution.
2. Draw the material under the low power objective, showing the relationship between size of fibres and field of vision and relationship of the fibres to each other.
3. Use scientific diagramming technique in your drawing.

D. Making a Permanent Slide

1. The procedure for making a permanent slide is almost the same as making a temporary slide.

2. There are only two changes: (a) water is not used. It is substituted by Canada balsam, (a permanent mounting medium). The balsam (sticky fluid) is taken out of the container with a glass rod.

   (b) a drop of the mounting fluid is placed on the specimen, not the specimen on the mounting fluid.

3. Place a coverslip as before over the specimen and allow the mounting fluid to dry for two to three days.

4. Place a label on one end of your slide, including the following information:

Specimen____________________ Date_____________ Name_________________

Life in the Biosphere 1.

Look out the window or take a walk outside. What do you see? There may be peaks or plains or houses in the background, rocks or dirt or pavement underfoot, clouds in the sky; a river or lake nearby, perhaps even an ocean; sunlight or moonlight coming from outer space. You may feel heat from the sun, or be cooled by a breeze, or be hit on the head by a hailstone or raindrop. You may breathe pure mountain air or be choked by smoke from a nearby factory. You may be standing in the middle of a desert or beside a red barn or at the foot of a twenty-four-story building or even in a junior high classroom. Wherever you are, you will find these kinds of things in your part of the biosphere. The things about you which have just been called to your attention represent the physical environment. But the physical environment is only one part of the biosphere.

You help to make up the other part of the biosphere: its living portion. For the biosphere includes every area of Earth where life occurs. Under the surface of the earth, on it, and above it, even in a space capsule--wherever there is life, there is part of the biosphere. All forms of life reside in the biosphere, large and small, plant and animal.

In this class you will explore the biosphere, especially that part which is called "life". Even if living things are very different from the physical environment, life and nonlife are very much tied together. There are interactions among the living things in the biosphere, and between life and the physical environment.

By his actions, man can have a great influence on the biosphere. We almost said "on his biosphere", but this would not be fair, because the biosphere really belongs to all the living things that occupy it, including man.

Man depends on the biosphere and interacts with the biosphere as the biosphere interacts with man.

Everyday we are quite aware of some biological problem facing man. Perhaps a newscaster says the smog level in our city is too high this month, or that the insecticides we use are poisonous and harmful to man and the animals he eats.

You have undoubtedly heard that the human population of the world is growing rapidly. Will he be able to produce enough food for all the people that will be born in the years to come.

Many lakes and streams are polluted - that is, they appear murky because they contain poisonous chemicals that kill living things in the water. In some places air, too, is heavily polluted.

What can industries and government do about this? What can man do about this as he is most of the cause of these problems.

Not everyone agrees on the importance of these problems or how to solve them. You may think the answers are simple. For example, if the blood disease malaria is carried by mosquitoes, then kill the mosquitoes! And this has been done. But is this the end of the story? Remember all living things interact with other things in the biosphere.

#1 Interaction of Man in the Biosphere.

The following detective story is imaginary, but it could happen!

THE SECRET OF THE SOGGY SWAMPS 2.

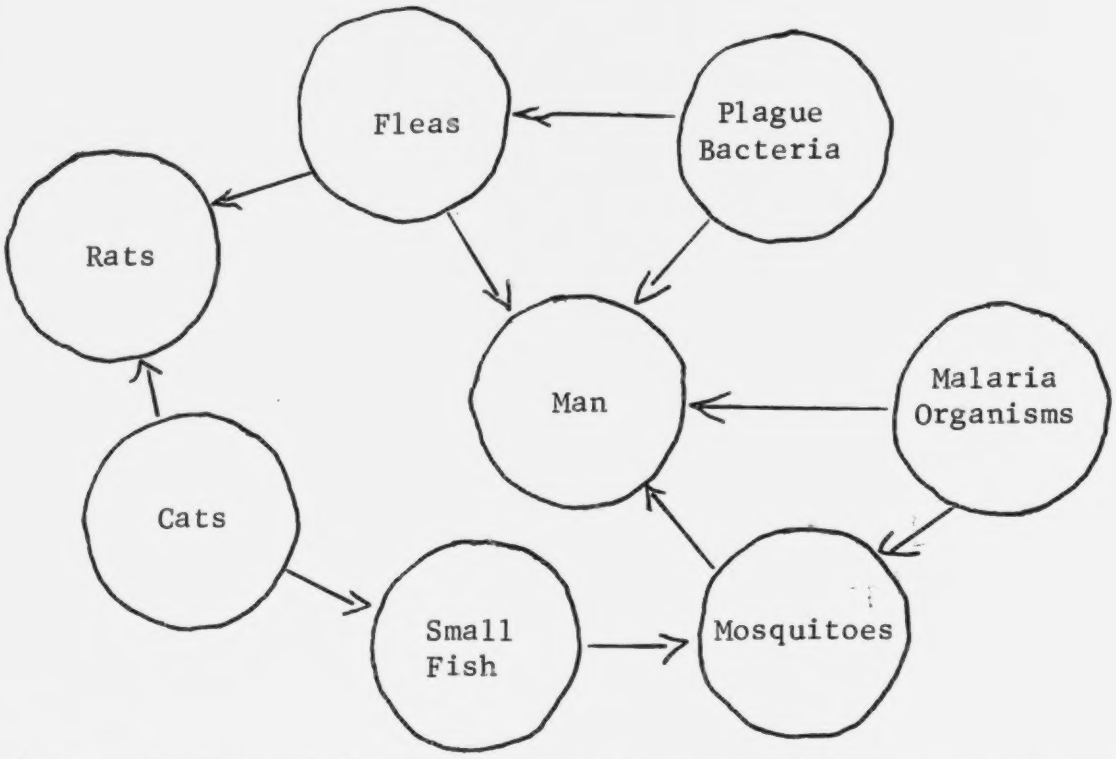
Dr. S. Holmes, a keen-minded physician, was sent to a small Asian country by the World Health Organization. A mysterious outbreak of plague, a bacterial disease that is carried by fleas, had killed many people in some villages. His first responsibility was to control the epidemic. But, to prevent similar outbreaks in other areas, he wanted to know what had caused this one.

He learned that there had once been many cases of malaria in the plague-ridden area, and so the swamps where malaria-carrying mosquitoes bred had been sprayed with DDT. After a time, people noticed more rats than usual. But there were few cases of malaria. Why should anyone worry about a few rats? Then, suddenly, the plague began.

Because of his knowledge of biology and medicine, Dr. Holmes solved the mystery. Using the above clues, he explained that the "villain" was the team of well-meaning men who sprayed the swamps!

What possible connection could there be between spraying swamps with DDT and a plague epidemic? As Holmes explained, "The fleas that carry plague live on rats. And the only apparent biological change in this area has been the killing of mosquitoes. I deduced that there must be some hidden connection. There must be an interaction between mosquitoes and rats that was not apparent to the health officials who tried to control malaria. DDT must have collected in bodies of small fish that ate the DDT-contaminated mosquitoes. The small fish were discarded by fishermen and eater by the village cats. The DDT in the fish killed the cats. The rat population increased because there were not enough cats around to

Figure 1. 1. The soggy-swamp food web.



eat the rats. More rats carried more fleas that carried more plague bacteria. And that caused the epidemic.

As Holmes realized, living things have many relationships among each other. Such relationships we call interactions. This is what Interaction of Man and the Biosphere is all about.

Question:

1. Explain what you think the arrows in Figure 1.1. stand for.

THE MINI-BIOSPHERE

To begin learning about the biosphere any where, whether wandering the streets of a city, sitting on a beach, or rowing across a pond, a scientist must gain experiences by studying a small part of the biosphere at a time.

As a beginning in your studies, let us look at a very small part of the biosphere. We might call it a mini-biosphere. From studying parts of a biosphere, it is an attempt through the year, to form a big picture of the biosphere.

Investigation 1 Mini-Biosphere

Problem: To investigate changes in a Mini-biosphere.

Design for Collection of Data:

Materials (for each team)

5 baby food jars, plastic dishes or finger bowls
(numbered 1 - 5)
fruit (a plum orange or lemon) very ripe
ripe grapes 5 - 10
hay or dried grass
stale bread
filter paper
soil
cornstarch
hand lens
slides
microscope
probes
spatula

Procedure:

Number each bowl from 1 to 5 and place the following materials in each.

Bowl 1 - Fruit, cut to fit into bowl.
Bowl 2 - Slightly crushed grapes, with sufficient water to cover.
Bowl 3 - Enough hay to cover the bottom of the bowl, add water till nearly full then boil.
Bowl 4 - Two pieces of bread, moistened in water. Note - first brush the pieces over a dusty area of the lab.
Bowl 5 - Place a piece of filter paper on the bottom of the finger bowl. Mix 5 grams of cornstarch with 95 grams of rich soil. While mixing the soil and starch, add enough water to give the mixture a dough-like consistency. Spread the mixture with a spatula to make a smooth surface. Keep the soil moist through investigations.

Observations:

1. Examine the bowls each day.

2. Indicate (a) the date of observation
   (b) the number of the bowl you observe
   (c) the microscopic appearance of the bowls contents
   (d) the appearance under a hand lens or misroscope (draw a diagram)
   (e) anything else you notice with your senses

In describing growth of organisms in the bowl consider color first, then size. In recording appearance of the growths you may find such terms as useful: fuzzy, cottony, powdery, smooth, rough, shiny, glistening, dull, compact, spreading, irregular. You should not limit yourself to these terms.

After good growth is maintained, make observations under a microscope. Place bits of growth on a clean slide with probes or if a liquid medium was used, place a few drops on a slide with a medicine dropper. Make sketches of what you see.

3. Make a permanent slide of one of the growths from a bowl. Label the slide at one end indicating the bowl number.

Intepretation of Data:

1. What evidence of growth appeared in the dishes? Where did most occur if any?
2. What happened to the food materials in each mini-biosphere?
3. What evidence supports the idea that these organisms are alive in each bowl?
4. Where did these organisms come from? Write down as many possibilities as you can think of.

New Problems and Application:

1. Some of the things we have used as foods for micro organisms are also food for us. We have seen what these micro organisms do to food, and clearly we must prevent such affects. Choose one food and investigate growth of micro organisms on it at various temperatures.
2. Compare organism growth on chemically treated food such as catsup and bread which have mold inhibitors as compared to homemade products.

New Problem: Are maggots generated spontaneously from rotten meat?

BACKGROUND INFORMATION

Life from Life 3.

When you think of "life", what first comes to mind? Is it movement, a rose, breathing, animals, a beating heart, or something else you associate with things that are alive? Think about this question and then define "life" as carefully as you can.

Now let us test your definition. Will it apply to all animals and all plants that you know? Will it apply to a pea seed, a developing egg of a chicken, a potato? Will your definition distinguish between the pea, the egg, and the potato when alive and after being cooked? Will your definition distinguish between a tree and a piece of firewood chopped from the tree?

The chances are that you did not succeed in making a definition of life that would work in every case. No one has ever done so.

When a scientist repeatedly finds himself unable to answer a question, he begins to wonder whether he is asking the right question - or whether he has asked it in the right way. This is our trouble now. The question "What is Life?" is too general to be studied easily in a scientific manner. Scientists have learned time and again that it is usually better to ask a very specific question.

For example, we might first have decided that the chief characteristic of life is movement. Probably all the animals with which you are familiar can move - fish swin, birds fly, and dogs run. We could ask our question: "Are all living things capable of movement?" The answer to this question could then be obtained by examining all the living creatures that we could find. Most of the things that we call animals would be found capable of movement. Some might be rather slow about it, however - think of snails. But what about mushrooms and trees? Do they move? Furthermore, a river moves, but is it alive?

Soon we would discover that "the ability to move" is not a very satisfactory definition of life. Some things that are alive do not move. Some things that move are not alive. If we are to define life adequately, all things that are alive must meet our definition, and no things that are not alive can be included.

We can work toward a definition of life that is adequate for nearly all purposes by asking some more questions. "Where do living things come from?" We can all answer that one for familiar plants and animals - they come from their parents. But can you answer the next question: "Do living things come only from other living things?" What about tiny creatures such as bacteria and viruses? Do they come only from other bacteria and viruses?

Questions of much the same sort have been asked for at least 2,500 years. You may be surprised, however, to learn that what now is regarded as the correct answer has been accepted for only a century.

The Experiments of Redi

Francesco Redi was a seventeenth-century Italian who was a physician to the family that ruled Florence. Like many physicians of those days, he was also a biologist. He was much interested in the question of the origin of the living, and he was, of course, aware of the belief that maggots are generated spontaneously from rotting meat. To him, unlike others, the belief seemed questionable. He decided to put the matter to a test of carefully controlled experiment and observation. His action was especially noteworthy because he lived in a time when it was customary

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3. Biological Science Curriculum Study, Biological Science, An Inquiry Into Life, second edition, Harcourt, Brace and World, 1968.

to seek answers to biological questions in the writings of Aristotle and other ancient authorities. Redi's approach is illustrated by an Arab proverb at the beginning of his book: "Experiment adds to knowledge, credulity leads to error." So he began to experiment. Here is a modified version of Redi's account of his experiments.

> PRELIMINARY OBSERVATIONS. The belief of ancient and modern authorities, as well as the popular belief, is that maggots are generated from decaying bodies and filth. Being desirous of testing this belief, I made the following experiment. I placed three dead snakes in a box and allowed them to decay. In three days the snakes were covered with small maggots. Eventually all of the flesh of the snakes was consumed and only the bones were left. On the nineteenth day some of the maggots stopped moving and behaved as if they were asleep. They seemed to shorten and taken on an oval shape, like an egg. Later they became hard little balls, resembling the pupae (PEW.pae) formed by caterpillars.
>
> I put some of these little balls in a glass vessel, which was then carefully covered with paper. After eight days the little balls broke open and out of each came a gray fly. At first the fly moved very slowly and the wings were closed. After a few minutes the wings began to unfold and soon a fly of normal appearance had formed. All the flies matured likewise.

So far Redi had repeated a familiar observation: maggots appear in decaying meat. Others would have interpreted the facts as illustrating spontaneous generation of maggots from decaying meat. But Redi had a different hypothesis.

HYOPTHESIS (Redi's)

Maggots are derived from the offspring of flies and are not derived spontaneously from the decay of meat. Such a hypothesis seemed likely, for I had observed flies hovering over the meat before it became covered with maggots. Furthermore, the files that hovered over the meat were of the same kind as those that later emerged from the meat.

DESIGN FOR DATA COLLECTION:

Equipment: 8 - wide mouth jars
2 - dead snakes
2 - dead fish
2 - dead eels
2 - slices of veal meat

1. Place one kind of dead animal into each of three jars and a slice of veal into a fourth. Seal these four jars.

2. Place one kind of dead animal into each of three jars and a slice of veal into a fourth jar. Do not seal the second set of jars.

3. Leave the jars for several days and observe the behavior of flies with respect to the jars and the condition of the meat within the jars.

OBSERVATIONS

1. Based on your experience what do you believe Redi observed with regards to flies and the two sets of four jars each?

2. Based on your experiences what do you believe Redi observed with regards to the decaying flesh and the two sets of four jars each?

Investigation 2

(LOUIS PASTEUR EXPERIMENT)

PROBLEM:

Is life found in the air?

BACKGROUND:

In the eighteenth century people still thought that microbes ('little animals') appeared mysteriously from materials such as mud, which is not alive. This idea is known as the 'theory of spontaneous generation' - suggesting that living things could suddenly be formed from non living things.

A scientist beyond his time, Spallanzani, tried to prove that liquids containing bacteria were boiled and sealed off, no microorganisms would be found. Thus he concluded that tiny living things could not be formed from something which is not living. However few people believed him as he lacked control in his experiment.

It was not until 1861, that the famous French scientist Louis Pasteur carried out a series of experiments to find out if bacteria could be formed from dead material in presence of air.

The following is a modified experiment of Louis Pasteur.

PROCEDURE:

1. You can try this similar experiment for yourselves. Into five test-tubes pour nutrient broth to fill each test-tube to about one-third.

Lab Activity 2-7

Test-tube 1.	Plug with sterile cottonwool but do not heat.
Test-tube 2.	Heat in a pressure cooker for fifteen minutes to sterilize. Leave unplugged.
Test-tube 3.	Heat in a pressure cooker for fifteen minutes to sterilize then plug with sterile cottonwool and tie several layers of tinfoil securely over the cottonwool.
Test-tube 4.	Heat in pressure cooker to sterilize. Plug with sterile cottonwool and insert a short glass tube.
Test-tube 5.	Heat in pressure cooker or autoclave for fifteen minutes to sterilize then plug with sterile cottonwool through which an open end of an S-shaped fine glass tube is inserted, the other end also being open to the air.

2. Number all the test-tubes and place them in a rack away from direct sunlight and the radiators. If bacteria are present in any of your test-tubes, they will probably turn the broth cloudy, or turbid. The amount of cloudiness is a rough indication of the number of bacteria present, and it will be important, also, to note when the broth starts to go turbid.

3. Record what you see on the third, fifth, and seventh days after you have set up your experiment, and again after two weeks.

4. Make a table of your results which might look something like this:

	Day 3	Day 5	Day 7	Day 14
Test-tube 1	Turbid	Turbid	Very turbid	Very turbid
Test-tube 2	Clear	Clear	Slightly turbid	Turbid
Test-tube 3	Clear	Clear	Clear	Clear
Test-tube 4	Clear	Clear	Clear	Slightly turbid
Test-tube 5	Clear	Clear	Clear	Clear

INTERPRETATION OF DATA:

1. Explain how Pasteur's "microbe trap" works.

2. How may you determine if the broth used in Pasteur's experiment is contaminated with microbes without using a microscope?

3. What is the meaning of the term sterile?

4. What is the meaning of the term turbid?

5. What interpretation can you make if broth turns from clear to turbid?

6. Look in Nuffield Text II at the bottom of page 16 and determine which test tubes would be the control samples if you were attempting to prove that bacteria are in the air.

7. Did the fact that the broth in test tube one was not sterilized have an influence on the speed at which the broth went turbid? Explain.

8. The broth in test tube two was sterilized, why did it turn turbid?

9. Examine the results of test tube three and five, why were they the same?

10. Why is test tube five similar to Pasteur's flask?

CELLS AND SOME CHARACTERISTICS OF LIFE

When you use a microscope to observe a drop of water from your mini-biosphere, you may see hundreds of tiny objects. Some may scurry along as if they were in a hurry to get from one place to another. Others may appear to swim lazily around in circles. Still others may not appear to move at all. Are all these objects alive? If they are alive, they all have one thing in common: each is made up of one or more cells.

A plant or animal may have one cell or many. Most of the small forms of life you see moving on the microscope slide prepared from the mini-biosphere are one-celled. Some of the larger forms that may appear later have many cells.

You might ask, "What does a cell look like?" But just as there are many different kinds of plants and animals, there are also many different kinds of cells. Cells vary greatly in shape. Some are round, others are shaped like boxes. Some may be long, cigar-shaped objects. A few kinds of cells change shape as they move. Still other cells, such as nerve cells, may have long branches extending from them. The variety of cell structure seems endless.

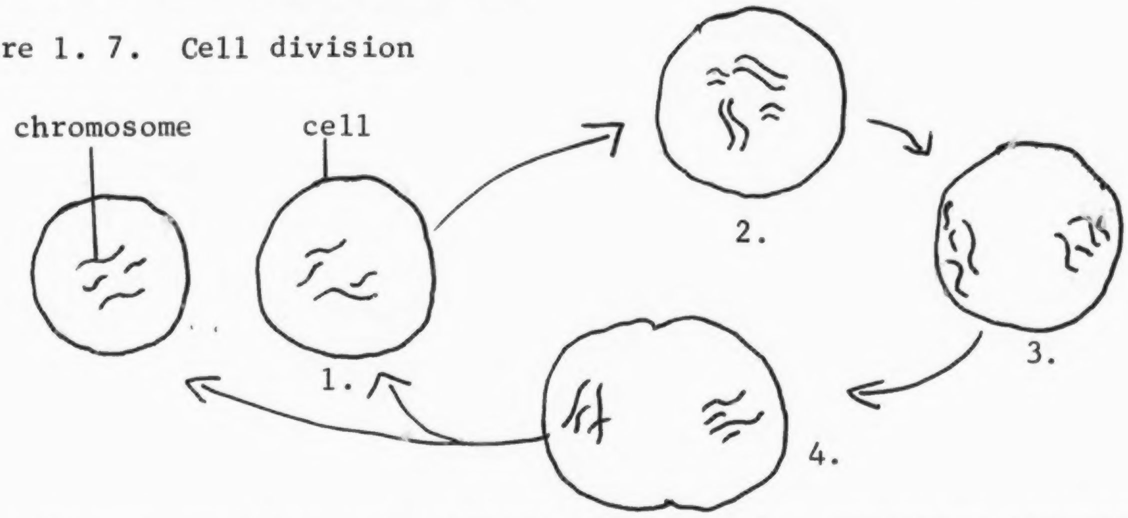
Some types of cells: To be completed by the student. (Draw diagrams.)

A cell has a very complex structure. In fact, scientists are not sure what some cell parts look like or what they do. And all cells are not alike inside, any more than their outside shapes are alike. Since cells vary so much, we cannot describe "a typical" cell that will have the characteristics of all cells. Almost every cell, however, contains a fluid that is surrounded by a membrane. This membrane is so thin that it cannot be seen with an ordinary microscope.

Contained within the cell fluid may be many small parts. Some of these are storage places for food, water, and waste materials. One important cell part is the nucleus. The nucleus seems to have some control over what happens within a cell--if the nucleus of a cell is removed, the cell usually dies.

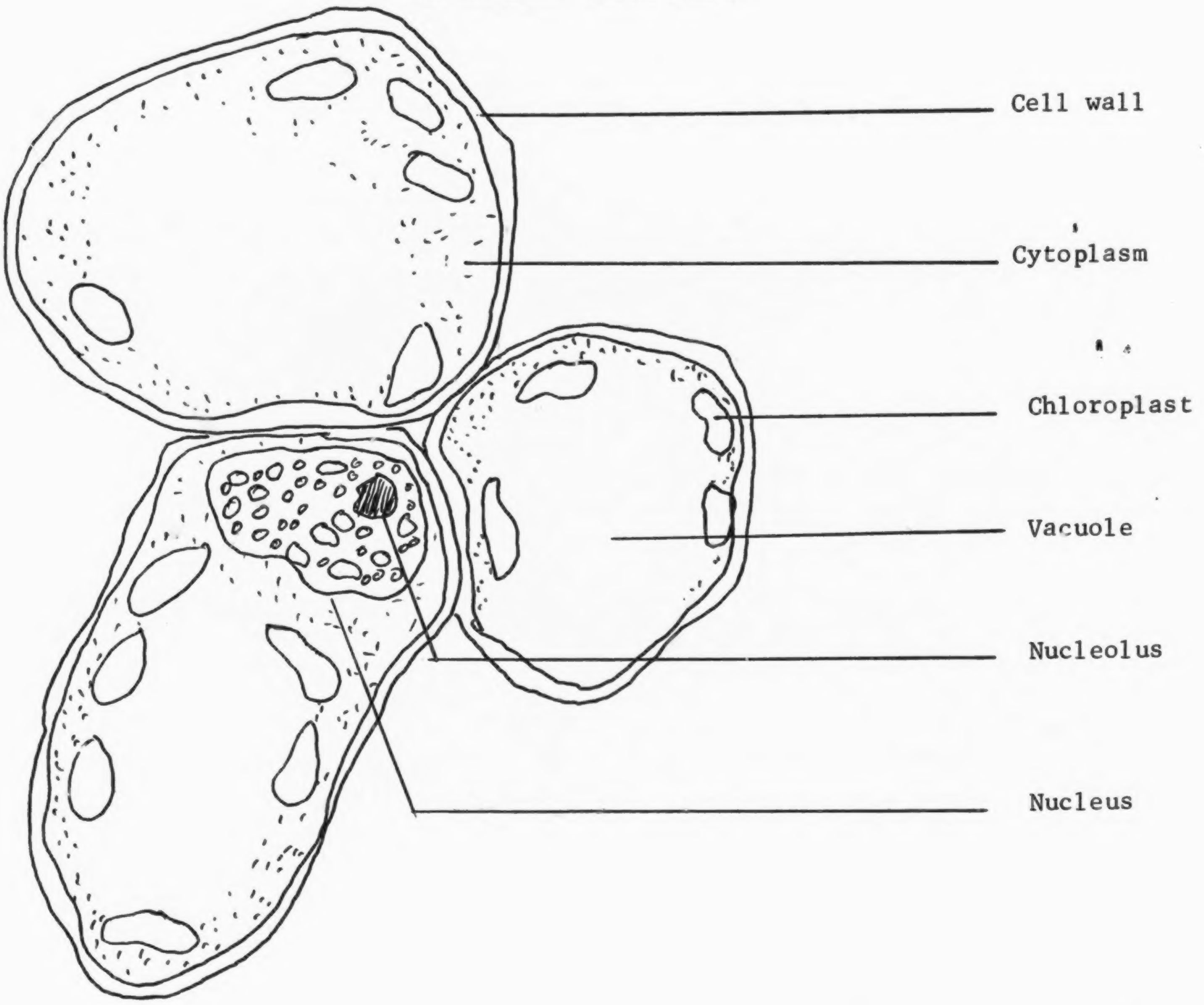
By the process called cell division, one cell becomes two, two cells become four, four cells become eight and so on.

Figure 1. 7. Cell division

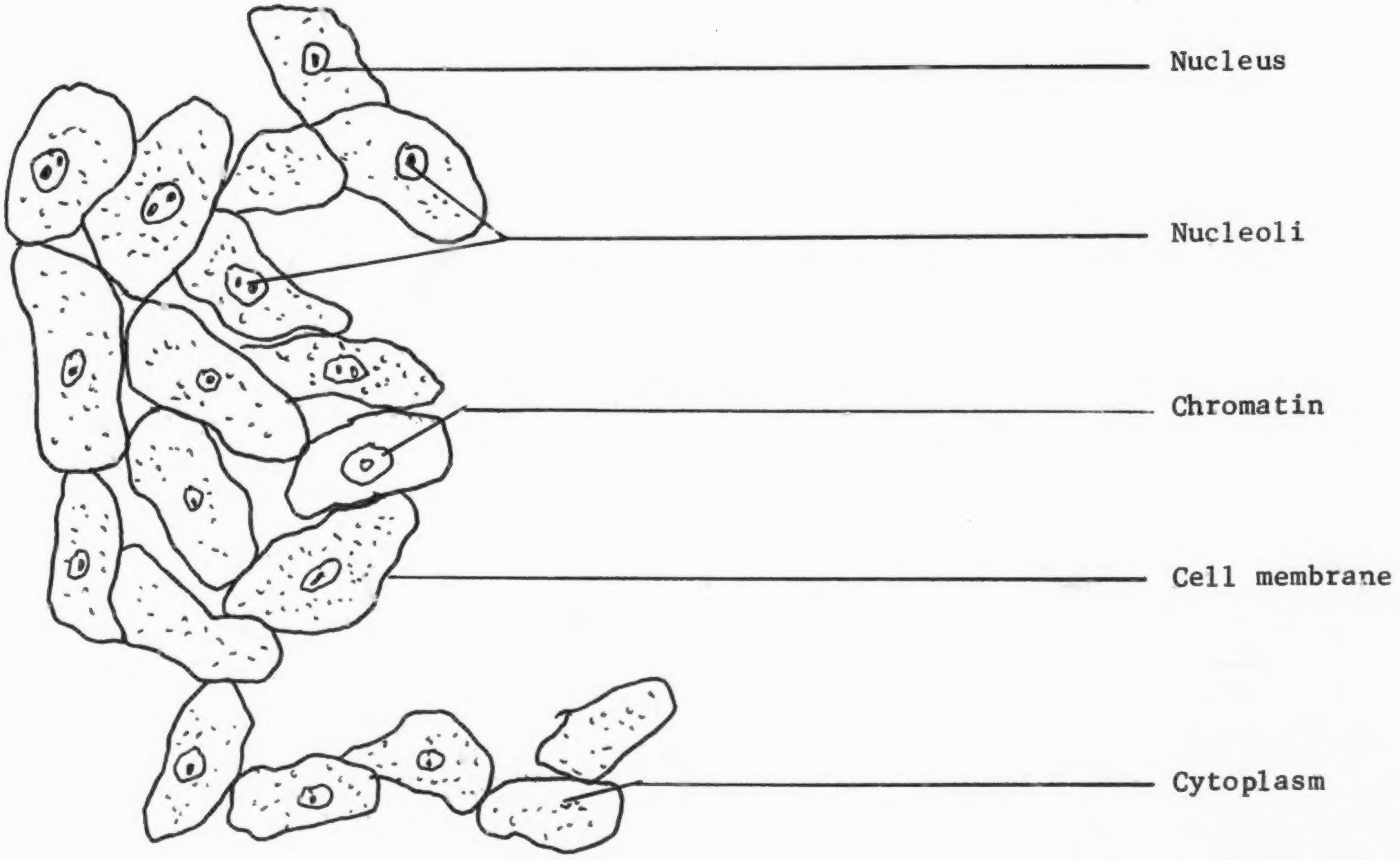

chromosome
cell
1.
2.
3.
4.

Thus, through repeated cell divisions, one-celled organisms increase in number, and many-celled ones increase in size. The human organism starts out as a single cell--a fertilized egg. From this single cell develop all the different kinds of cells that make up the human body--brain cells, muscle cells, bone cells, blood cells, and so forth.

GENERALIZED PLANT CELLS


Cell wall
Cytoplasm
Chloroplast
Vacuole
Nucleolus
Nucleus

GENERALIZED ANIMAL CELLS



Investigation 3
UNIVERSITY IN CELL STRUCTURE

PROBLEM: To compare the structures of several different kinds of living cells -- as far as these structures can be seen with a light microscope.

Design for Collection of Data

MATERIALS AND EQUIPMENT (for each team)

Onion, cut into pieces about 1 cm
Forceps (fine-pointed)
Microscope slide
Scalpel
Medicine droppers, 3
Cover slips
Monocular microscope
Iodine--potassium-iodide solution (I_2Kl)
Paper towels
Elodea leaves
Toothpicks (sterile)
Psychological saline solution
Methylene blue solution
Dissecting needles, 2
Frog blood or animal blood from a slaughter house
Frog skin

PROCEDURE:

1. You will be provided with small pieces of onion. On the inner, concave, side

the skin (epidermis) may be readily peeled off with forceps. Place a small piece of epidermis (much smaller than a cover slip) on a slide, avoiding overlapping or wrinkling. Add one or two drops of water and a cover slip.

2. Examine the onion epidermis under the lower power of the microscope. Look for cell boundaries. Draw a small section of the field of view to show how the cells are arranged.

3. Place a drop of iodine -- potassium-iodine stain along one edge of the cover slip. Pull it under the cover slip, using the technique given in your guide.

4. Record any changes that occur as the stain spreads across the onion epidermis. Then switch to high power and draw a single cell, including as much detail as you can see. Label all the parts you can identify. Even with the high power of your microscope, you will be able to see only a few of the parts known to occur in cells.

(Note: Be sure to clean slides thoroughly with water and paper towels before placing another kind of material on them)

5. With forceps remove a young leaf from near the tip of an elodea plant. Place it on a clean slide and add a drop of water and a cover slip. Observe the leaf under low power. By slowly turning the fine adjustment back and forth, determine the number of cell layers in the leaf. Switch to high power. Select an average cell and focus on it carefully. Is there any evidence that the cell is living? If so, what is the evidence? Make a drawing of the cell, including as much detail as you can see. Label all the parts that you can identify.

6. Using the blunt end of a sterile toothpick, scrape the inside surface of your cheek. Do not dig a hole in your cheek; you should obtain a barely visible mass of material. Rub this material on a clean slide. Add a drop of physiological saline solution and stir thoroughly with the toothpick. Examine under low power. By carefully using the fine adjustment, try to observe the three-dimensional shape of the cells. Would you describe them as spherical, disk-shaped, or neither? Add a drop or two of methylene blue and a cover slip. Find several cells well separated from the others. Draw one or two of them, including as much detail as you can see. Label all the parts that you can identify.

7. Place a drop of diluted frog blood on a clean slide. Add a drop of methylene blue and a cover slip. Most of the cells to be seen are red blood cells. Find an area where the cells are neither too crowded nor too scarce and center it in the field of view. Switch to high power. Draw one or two cells and label all the parts that you can identify.

8. Place scrapings from a frog's skin on a clean slide. Add a drop of physiological saline, one or two drops of methylene blue, and a cover slip. Locate cells with low power and then switch to high power. Draw one or two cells and label all the parts that you can identify.

OBSERVATIONS:

Draw a table like the following one, allowing a column for each kind of cell structure observed.

SOURCE OF CELL	CELL WALL	CHLOROPLAST	NUCLEUS
Onion epidermis			
Elodea leaf			

Review your sketches and notes. For each kind of cell examined, place an X beneath the name of each cell structure observed. Does the lack of an X indicate that the structure was not present in the cells observed? Why or why not?

On the basis of your observations, which kind of cell (plant or animal) seems to have more angular, less rounded shapes? Which has more clearly defined boundaries? What cell structure may be involved in these characteristics?

INTERPRETATION OF DATA:

1. What is the cell theory? What evidence have you found to support the cell theory?
2. What differences or similarities do the cheek cell have compared to the onion cell?
3. Most green plants grow in an upright position. Explain how structure of plant cells might account for this.

Investigation 4

ANOTHER BIOSPHERE? 4.

Scientists try to find answers to questions. Usually a scientist must carry out many experiments to find the answers he seeks. He may work either in a laboratory or outdoors, depending on the kind of problem he wishes to investigate.

Scientists often work in teams. There is a good reason for this. One person working alone may not have as many useful ideas as several people working together. And useful ideas are very important in scientific work. Remember that each person on a team must offer ideas if the team is to be successful.

Imagine that you are a member of a team of scientists that has just landed on Planet X. You want to determine whether there is life on the planet. If there is, of course, it would represent another biosphere!

You find that you can leave the space ship and breathe the planet's air without trouble. In this respect, at any rate, the new planet is very much like our own biosphere. Each of you spends several days exploring the area without finding any green plants, moving animals, or other signs of life. Members of your team do collect five different kinds of strange materials. Your task is to determine whether any of the materials collected on the planet are living things. What would you do?

Your laboratory investigation will be to determine if any of five different materials are living things. In this way you will experience the same kind of problem as our imaginary space scientists, who are hoping to discover another biosphere.

PROBLEM: To determine if unknowns are living or non-living.

NOTE: DO NOT TASTE ANY OF THE MATERIALS. You do not know whether or not they are posionous.

4. Interaction of Man and the Biosphere.

DESIGN FOR COLLECTION OF DATA

MATERIALS (per team)

Samples of five "unknown" substances
Magnifying glasses
Some chemicals
Miscellaneous glassware
A source of heat
Paper cups

PROCEDURES:

A. Make a list of the standards you plan to use in deciding whether the materials are living or nonliving.

B. In your notebook copy the chart in Figure T-1. 1. Label each sample with a number. Using a magnifying glass, examine each of the materials. In your chart record what each looks like. Under the column headed "your prediction," place a check mark to indicate whether you think the unknown is living or nonliving.

Figure T-1. 1.

UNKNOWN NUMBER	COLOR	SHAPE	OTHER DESCRIPTION	YOUR PREDICTION	
				LIVING	NONLIVING
1					
2					
3					
4					
5					

C. Plan several methods that might allow you to find out which of the unknown materials are alive. For example, you might do the following:

1. Place water on each unknown and see if anything happens.
2. Examine each unknown material under a microscope.

Whatever methods you choose, keep a careful record of what you do and of what results you obtain.

D. Your investigation should take several days. When you have finished, report your discoveries to the class.

INTERPRETATIONS;

1. Were you able to predict which of the unknown materials are living?

2. Have you proved that some of the unknown materials are not alive?

3. On what basis could you decide that Planet X was another biosphere?

4. If you did find living things on Planet X how might they have gotten there? Remember your earlier discussion in Investigation 1. 1.

5. Why is there an agreement between the United States and Russia that any unmanned space vehicle headed for a landing on the moon or another planet be carefully sterilized (that is, all earthly organisms on it be completely destroyed) before launching? How may manned landings complicate this problem?

UNIT IV

LIFE PROCESSES

LIFE PROCESSES

The Teacher's Notes for this unit are of two types: General, relating to life functions as a whole and notes for specific investigations.

Responsiveness

The laboratory activities suggested in the unit of material "Responsiveness" have not been used in the classroom and for this reason there are no suggestions to the teacher that have been based on teaching experience with these materials. However, there are some things that the Life Science instructor should be aware of before he begins to use the following activities in the classroom. There is a great deal of preparation that must be carried out before the lessons can begin in the way suggested by the students' manual. We would ask that the teacher read the materials well before the class is to begin in order to make arrangements to have available in the classroom the live specimens that are suggested. Also, the teacher should ensure that the students have very clear instructions as to how they should proceed with their investigations as the unit suggests many different activities (minimum of six) should be done at one time.

Respiration and Nutrition

By careful selection from the 18 investigations provided, the teacher may cover these life processes. It should be noted here that it is not necessary to cover ALL the investigations and that teachers should feel free to substitute their own materials where they deem it necessary.

1. Adapted from units developed by Lloyd Pearce and Reg Roberts

THE LIFE PROCESSES - GENERAL

A. WHAT DO WE MEAN BY "LIFE PROCESSES"?

Living things must carry on certain activities to keep themselves alive. These activities may be called life processes because they are essential to life. They distinguish the living from the non-living.

All life processes occur basically in the cells of living things. They all involve physical and chemical changes within the cells and all require energy. The energy is obtained from foods which is broken down through the process of oxidation. Green plants are able to manufacture their own food while animals must depend upon plants or other animals for their food supply.

B. WHAT FUNCTIONS ARE INCLUDED IN THE LIFE PROCESSES?

1. Responsiveness

Living matter is known as protoplasm and is highly responsive. That is, it reacts to many different stimuli. Astimulus is anything that initiates the response in the protoplasm. This characteristic of responsiveness has also been called irritability. Heat, light, sound, pressure and innumerable other things may be stimuli to which living things respond in very definite ways.

2. Respiration

Respiration occurs in all living cells. Respiration is a series of processes whereby the energy of food is released. Oxygen is required for the release of the stored energy in foods and this is why oxygen is needed by all living things. Respiration occurs in cells and should not be confused with breathing.

3. Nutrition

Protoplasm is composed of matter, and it is necessary for all living things to obtain materials for the growth and repair of protoplasm. This means that organisms must secure food and that the food must be in such a form that it can be used by the protoplasm. The life activities concerned with obtaining and using food are grouped under the general term nutrition. Most food is not readily usable and has to be broken down into simple substances which the cells can use. This breaking down of complex food substances into simple, usable substances is known as digestion. Practically all living things carry on the digestive process. Other features of nutrition are absorption and assimilation. Absorption involves the intake of materials into cells, and assimilation refers to the use of the food in making new protoplasm.

4. Excretion

The removal of wastes is known as excretion. Wastes must be removed from the cells and from the body in order for the cell and the organism to continue to function properly.

5. Growth and Reproduction

Growth is a characteristic of living things. Cells may grow through increase in size. The size of a living thing may also get larger by an increase in the number of cells in the organism. This is brought about by a single cell dividing into two cells. The process by which cells divide is called cell division.

The process by which living things give rise to new organisms is known as reproduction. There are several ways whereby new organisms are formed. In one method, organisms are formed by simple cell division. In another method certain cells known as germ or reproductive cells are formed. From the union of reproductive cells, a fertilized egg is formed and the fertilized egg, through cell division, develops into a new organism.

C. HOW DO UNICELLULAR AND MULTICELLULAR ORGANISMS CARRY ON THE LIFE PROCESSES?

1. Unicellular Organisms

In unicellular organisms the life processes are performed by the protoplasm and by the specialized structures or organelles within the cell. The cell nucleus regulates all the activities of the cell.

2. Multicellular Organisms

In multicellular organisms, as in unicellular organisms, the life processes are performed by the individual cells. However, since multicellular organisms have large numbers of cells, there is a division of labor by which certain cells, tissues and organs are organized to perform only certain functions. As a result, the bodies of the higher organisms are composed of systems which are specialized to carry on specific functions related to respiration, excretion, and the other life processes.

SUBCONCEPTS

Responsiveness

a) Living things have different ways of receiving external stimuli.

1. Stimuli receptors have been highly developed in many organisms but not in all.
2. Organisms gain information about their surroundings through their senses.
3. The structure and sensitivity of stimuli receptors seemed to be related to the environment in which the organisms live.

b) Living things respond to stimuli.

1. Different organisms may respond to the same stimulus in different ways.
2. The structure of the receptor and the way in which an organism responds to a stimulus is often related to its survival.

c) Living things are adapted to the environment in which they live.

d) There is a dynamic equilibrium between the stimulus (environment) and the response (behavior) of an organism.

While the preceding subconcepts are implicit within the lesson materials the instructor may use every opportunity to culminate student investigations by leading post-laboratory discussions to the discovery of the subconcepts. Some formal lessons, after activities have been completed, should be structured to meet this objective and to draw the students' attention not only to the stimulus -- response behavior of organisms, but also to the interdependence of the organisms structural adaptations, behavior, and environment. For example, keen eyesight allows the organism to live and behave in a certain way and in environmental conditions that may not be possible for an organism with poorer eyesight. Also, the development of keen eyesight was influenced by the organisms having to live in that environment.

The instructor should balance discussions and activities between plants and animals and not neglect the plant group.

Respiration

All organisms require energy to carry on the processes of living. Most of this energy comes from food as it unites chemically with oxygen. Oxidation of food within the body is much more complicated than the oxidation of fuels during burning. The process requires many different chemicals and several different steps, some of which are not well understood.

Respiration begins with the intake of oxygen and the transporting of the oxygen to parts of the body where energy is needed. It ends with the release of energy stored in the foods. In its narrowest sense, respiration refers to the intake of food and oxygen by the cells and the release of energy and carbon dioxide. In its broadest sense, it refers to all of the events concerned with getting oxygen to the cell and disposing of carbon dioxide. Respiration in highly complex organisms involves not only the respiratory system (to provide oxygen) but also the digestive system (to provide the food), the circulatory system (to carry the oxygen and food to the cells) and the excretory system (to carry away the carbon dioxide and other wastes).

Respiration in Unicellular and in Multicellular Organisms

Unicellular organisms are in direct contact with their environment and are therefore able to absorb oxygen and release carbon dioxide without depending upon other cells. Multicellular organisms, however, are much more complex and most of the cells are not in direct contact with the external environment. As a result, oxygen cannot be absorbed directly from the surroundings and carbon dioxide and other waste products cannot be given off directly to the atmosphere. In such cases, each cell is dependent upon other cells to provide oxygen (and food) and take away carbon dioxide and other wastes. Cells become specialized into tissues, organs and systems to provide all other cells with a means of "communication" with the external environment.

At the cellular level, all respiration, whether in unicellular or multicellular organisms, involves the diffusion of oxygen through moist membranes and into the cell cytoplasm, and the movement of carbon dioxide in the opposite direction.

Respiration and Energy

The main feature of respiration is the release of energy. The foods used by cells as sources of energy are carbohydrates, proteins and fats. Glucose, a carbohydrate, is the most important energy source. It is usually the first material used in the series of chemical steps which ultimately provide energy for the cell. This energy is stored in the form of a substance known as ATP (adenosine triphosphate), a compound which has three phosphate groups in its molecule. ATP is often compared to a coiled spring which has been tightly compressed. When one of its phosphate groups is taken up by another molecule, energy is released just as the energy in a compressed spring would be released if you removed the force that was holding the spring down. ATP is the immediate source of energy for all living things and all processes are dependent upon this compound for their energy. It is in the mitochondria of each cell that ATP is formed.

Methods of Respiration

Organisms must live in environments where oxygen occurs. Those which live on the land must obtain their oxygen from the air which surrounds them. Aquatic organisms must obtain their oxygen from the water in which they live. The membranes through which oxygen and carbon dioxide pass must not only be porous but also moist.

In small animals the intake of oxygen and release of carbon dioxide can occur entirely through the surface of the body. This is because the body surface is large compared with amount of living material requiring oxygen and giving off carbon dioxide. The inner cells receive their oxygen supply by diffusion from the outer cells.

In larger animals, the body surfaces are not large enough to provide all the oxygen which is needed. Therefore, these animals have organs which greatly increase the surface area through which oxygen and carbon dioxide can be exchanged. In aquatic animals these organs are usually feathery or plate-like structures called gills. In land animals, air tubes and sacs (lungs) are used. In all cases, exchange of oxygen and carbon dioxide takes place through moist, porous membranes.

Breathing

Breathing is not to be confused with respiration. It does not mean the same thing as respiration but rather is only one of the processes involved in respiration in some animals. Many animals have special organs inside their bodies for the exchange of oxygen and carbon dioxide. The movement of air into these organs from the external environment and the movement of air from these organs back out to the external environment is known as breathing. Breathing, generally speaking, is simply a method of getting oxygen into the blood and removing carbon dioxide from the blood. It occurs basically in only those animals which have lungs.

Transportation of Gases To and From the Cells

Once the oxygen is absorbed from the external environment by the "breathing" organ (skin, gills, air tubes or lungs) it must be transported to the inner cells which are found deep within the body. In the higher animals it is the blood which does the work of transporting or "circulating" the oxygen to all the cells and carrying away the carbon dioxide. The blood then is basically a transporting fluid. It normally flows through a system of tubes and is forced along these tubes by a pump or heart. At certain points along these tubes, oxygen leaves the blood and enters the cells while carbon dioxide leaves the cells and enters the blood.

CIRCULATORY SYSTEMS

In Simple Animals

The cytoplasm of all cells is in constant motion. In one-celled organisms this movement provides an adequate means of transporting oxygen and other materials to all parts of the cell. In many of the multicellular organisms, almost all of the cells are exposed to their external environment so that each cell can obtain its own oxygen and get rid of its own wastes. Those cells which are not exposed are usually not very far from those that are. In these cases, diffusion provides a means of transport. The beginnings of circulatory systems are first seen in simple worms such as the roundworms. Some of these worms have fluids in their body cavities. As the worm wriggles around, the fluids are squeezed about from place to place.

In Higher Invertebrates

Most animals which have body fluids also have tubes through which these fluids move. The fluids are moved through the tubes by means of a pumping device and the direction of flow is controlled by valves within the tubes. Gases can enter and leave the fluids only when the fluids flow slowly and are in tubes with very thin walls.

In arthropods and most mollusks, blood is pumped through tubes that empty into body spaces. The blood flows very slowly through these spaces and comes into close contact with the tissues. From these spaces the blood eventually gets back into another set of tubes which then carry it back to the pumping organ. In other words, the blood does not always flow through tubes. Such a system in known as an open circulatory system.

Annelids have a closed circulatory system. The blood is completely enclosed in tubes throughout all parts of the body. At no time does it leave these tubes and pass out into body spaces.

In Vertebrates

All vertebrates have closed circulatory systems. The blood flows through three types of tubes (vessels): arteries, veins and capillaries and is pumped through these tubes by a heart which consists of two or more sections or chambers. Arteries are joined to veins by means of capillaries. Oxygen, carbon dioxide and other materials can pass through the thin walls of capillaries. The exchange of materials between the blood and the tissues can take place only through the walls of the capillaries. Every cell in the body is next to, or very close to, a capillary.

NUTRITION

In order to carry on the life processes, the cells of living things must have not only oxygen but also food. Food is needed to provide the energy to carry on these processes. When the food is combined with the oxygen (during oxidation), energy is released.

Producers and Consumers

Living things can obtain the food they need in one of two ways. They can either make it themselves or obtain it from other living things. Those living things which are able to make their own food are known as producers. Green plants are the food producers of the world. They are capable of trapping the sun's energy and using it to manufacture food. The food that green plants make supplies the whole living world with the materials and energy needed to maintain life. All other living things depend, in one way or another, on green plants to meet their food requirements. They consume, or use, food which was first made by green plants. For this reason they are given the general name consumers. All of the animals are consumers and so are many of the simple plants such as bacteria, molds and mushrooms.

Primary consumers are those organisms which feed on the green plants (producers) directly. They are also known as herbivores. Since their food consists only of plant materials, they have digestive systems which are adapted by structure and function to handle this type of food.

Those organisms which feed on the primary consumers are the flesh eaters or carnivores. They are called secondary consumers. Some of them must catch and kill the animals they use for food so they are equipped with structures such as teeth and claws which are adapted for this function. Others do not kill their own meat but rather feed upon the bodies of any dead animals they may find. They are known as scavengers. Those animals which feed on both plants and animals are known as omnivores.

Food Chains

As you have seen above, food that was first made by plants (producers) may be eaten by plant eaters (primary consumers or herbivores). Plant eaters are eaten by flesh eaters (secondary consumers or carnivores). Flesh eaters may be eaten by other flesh eaters (secondary carnivores). These die and may be used for food by the scavengers. Meanwhile, some of these forms are fed upon by parasites. Whenever food is passed along in such a manner we have what is called a food chain. Energy is passed along from one organism to another. At the start of the food chain, there are numerous small organisms. The end consumers die and their bodies are changed back to the elements and compounds from which they were originally made.

Processes Involved in Nutrition

Nutrition involves the processes by which organisms either:
(1) produce their own food (by means of photosynthesis) or
(2) obtain food from other organisms, distribute it throughout their bodies and use it to carry on life functions.

PHOTOSYNTHESIS

Photosynthesis is the process by which green plants manufacture food. It includes all the physical and chemical reactions which are involved in the trapping of the sun's energy and the use of this energy to produce food. The raw materials, water and carbon dioxide, are combined chemically only in the presence of light. The word "photosynthesis" is derived from "photo" which means "light" and "synthesis" which means the "putting together of parts."

Discoveries which have Helped Our Understanding of Photosynthesis

Man has always used plants as sources of food, but he has not always completely understood how this food is manufactured in plants. Aristotle, an early Greek scientist, believed that plants took in materials through their roots. Van Helmont, around 1600, tried to find out how a tree secured its food. He planted a tree of known weight in a given amount of soil. After five years, he found that the weight of the tree had increased by over 150 pounds while the soil had lost only a few ounces. Where did this increase in the tree's weight come from and from where did the tree obtain the materials that made up the increased weight? Van Helmont felt that most of the materials did not come from the soil but rather from the water that he had added during the experiment.

The next significant discovery about photosynthesis was made by Joseph Priestley in 1772. He found that green plants could "restore" bad or fixed air. (At that time carbon dioxide was called fixed air.) Priestly noticed that a mouse would die when placed in such air. However, he discovered that if he placed a green plant in a jar of this fixed air (carbon dioxide) and left it for a period of time, the good air (oxygen) would be restored. If a mouse were placed in the "restored" air, it could live as long as in ordinary air. This discovery eventually gave rise to the idea that plants give off oxygen during sunlight hours.

In 1778, Jan Ingen-Hausz found that light was necessary to bring about the "restoring" of bad air. He also discovered that plants give off fixed air. This helped to establish the belief that carbon dioxide is given off by all living things. Another idea held by Ingen-Hausz was that carbon dioxide was the source of the carbon used by plants in growth and that the oxygen from the carbon dioxide was given off as a waste product. He proposed this idea in 1796, but it was not until the next century that Van Niel showed that the oxygen given off by green plants comes from the breakdown of water.

In 1804, Nicholas de Saussure showed that growth in plants results from the intake of not only carbon dioxide but also water. He concluded from his experiments that water was also necessary for the making of food. In 1837, Dutrochet stated that only plants that contain the green substance chlorophyll can manufacture food. He also introduced the idea that possibly the carbon dioxide taken in by plants enters the leaves through tiny openings called stomates.

It wasn't until 1862 that it was discovered that plants manufacture starch in their leaves. This discovery was made by Julius Sache. He also showed that starch was found in the leaves only during the daylight hours and disappeared at night.

By the beginning of the twentieth century it was known that green plants, in the presence of sunglight, take in carbon dioxide and water and from these two raw materials manufacture food. It was also known that oxygen is given off during this process. However, no scientist had yet explained the steps by which carbon dioxide and water were used in the making of food. It was not until 1961 that this problem was solved through the efforts of Dr. Melvin Calvin.

While much has been learned about photosynthesis, there are still many unsolved problems. Scientists throughout the world are continuing to delve deeper and deeper into the mysteries of food manufacture in green plants.

Where Does Photosynthesis take place in Green Plants?

Photosynthesis takes place in all of the green cells of plants. The green pigment is composed of a substance known as chlorophyll. Chlorophyll normally is found in tiny structures inside of the cells called chloroplasts. Chloroplasts are found most often in the leaves of plants. However, they may also be found in stems, particularly in young plants. Wherever they are found, photosynthesis may take place.

Comparison of Photosynthesis and Respiration

As you have already learned, respiration is a process in which food is broken down (by oxidation) and energy is released. In photosynthesis food is built up and energy is used. Photosynthesis uses carbon dioxide and produces oxygen. Respiration uses oxygen and produces carbon dioxide.

Photosynthesis gives the plant a supply of food (glucose) for its cells. This food supplies both energy and building materials for the plant. Energy stored in the glucose molecules can be used by the plants wherever it is needed.

Green plants carry on both photosynthesis and respiration. Animals (and non-green plants) carry on only respiration. During respiration both plants and animals give off carbon dioxide. This carbon dioxide goes into the air (or water). From the air, the plants obtain the carbon dioxide they used for photosynthesis.

Photosynthesis	Respiration
Building up process	Breaking down process
Food produced	Food used (consumed)
Energy from sun stored up	Energy released
Carbon dioxide taken in	Carbon dioxide given off
Oxygen given off	Oxygen taken in
Complex compounds formed	Simple compounds formed
Glucose produced	Carbon dioxide and water produced
Goes on only in light	Goes on day and hight
Takes place in cells with chlorophyll	Takes place in all cells

Photosynthesis and respiration do not balance each other in a green plant. In bright sunshine, photosynthesis occurs at a rate ten times more than that of respiration. At night, of course, photosynthesis stops while respiration continues. However, the total photosynthesis carried on by a plant far exceeds the total respiration. This emphasizes the importance of green plants as the food and oxygen producers for all other life on earth.

Investigations Into Phototsynthesis in Green Plants

In the investigations which follow, you will be studying the structure of leaves and how they are adapted for the function of photosynthesis. In addition, you will investigate the role of chlorophyll, light and carbon dioxide in the photosynthesis process.

Photosynthetic activity is usually measured in terms of the amount of starch which is produced in the leaves. In other words, the best evidence to indicate that photosynthesis has taken place in a leaf is the presence of starch in the leaves. It has been shown experimentally that when a plant is actively undergoing photosynthesis much of the sugar produced in the chloroplasts in the leaves is converted to starch. As a result, the starch test involving Lugol's solution or iodine solution is commonly used to find out whether or not photosynthesis has taken place.

The main photosynthetic organ in higher plants is the leaf. It is well adapted to carry out the function of photosynthesis because it has specialized structures which perform special jobs. Special cells regulate the entry and exit of gases into the leaf; special cells contain chloroplasts which produce the sugar; special cells bring raw materials to the leaf and carry away the manufactured food.

NOTE:

Because of the shortage of time, investigations related to nutrition in animals (consumers) were not developed. These investigations, which will be developed in a later edition, will deal with the following concepts:

1. A variety of consumers utilize the food of the primary producers
   a) Consumers have a variety of ways of ingesting and digesting food
   b) Diffusion and osmosis are fundamental processes in the movement of food

2. There is a chain of energy distributed from primary producers to a variety of consumers (primary, secondary, tertiary) resulting in a balance of nature.
   a) There is a change in biomass as you go from one trophic level to the next

TEACHERS' NOTES FOR INVESTIGATIONS

Investigation 1

Preparation

Living organisms must be brought into the classroom in order to complete the suggested investigations. The instructor may wish to introduce the lesson materials to the student, have each one select an activity in the background information and then arrange a field trip to allow the students to collect the specimens he will need. What the instructor must ensure is that the students make a commitment to care for the specimens during the investigation. A small team of students may maintain the entire collection or the individual students may care for their own collections, but some standard of maintenance should be established for each species of organisms before they are brought into the classroom.

Problem

Discussion of the intent of the problem. What direction can the student expect from the statement of the problem? Determine the precise meaning of the terms "respond" and "stimuli".

Operational Definition

This definition may be formed by the students on the basis of a teacher demonstration. The demonstration should be very short and of the nature whereby the student's response is immediate. E.g., slapping a ruler on a student's desk, suddenly asking for quiet in a loud voice, flicking the hand near a face, suddenly begin to laugh, tickle a nose.

Background Information

Following the student's selection of an activity ensure that his procedure will give reliable observations. Your approach to this aspect of the activity will vary from student to student, depending upon the background of the student. The more capable students should receive little help on their procedure and should be asked to redraft it until an experiment that has scientific value is described.

Activity A

1. Observation - as the temperature decreases, so does the rate of movement of pulse at the throat of the frog.
   Interpretation - temperature influences the pulse rate of a frog.
   New Problem - is the pulse rate of cold-blooded animals influenced the same way by temperature changes?

2. Observation - the rate of gill movement of a guppy decreases as the temperature decreases and increases as the temperature increases.
   Interpretation - the temperature influences the respiratory rate of guppies

The range of temperatures that the guppies may be exposed to should probably not exceed the range of 50 - 90°F and exposure to these temperatures should not be extended over too long a period of time. Following these sudden temperature changes, the fish should be treated for "Ich" (contact local pet shop). In place of guppies, a field trip may be arranged to collect minnows from local lakes and streams. However, wildlife are likely to have less tolerance to high temperatures and it is probably necessary to lower the suggested temperature ranges. Also the wildlife would need an opportunity to adjust to the captivity and have to be observed in quiet surroundings.

New Problems - is the respiration rate of each species of fish influenced in the same way by temperature or are some species less sensitive to temperature change.

3. Observation - the lower the temperature the slower the generation of of gas by yeast and the higher the temperature the faster the generation of gas.

Interpretation-the temperature influences the rate of generation of gas by yeast.

New Problem -does the amount of sugar influence the rate of generation of gas by yeast?

Activity B

1. Observation - the planaria swim away from the drop of ammonium hydroxide.

Interpretation-the chemical, ammonium hydroxide caused the planaria to leave that region of the petri dish.

New Problem -do planaria respond in the same way to all chemicals when introduced in weak solutions. (e.g., drop of blood from fresh liver).

2. Observation - the nematocysts of the hydra are ejected when the acid diffuses through the water in the slide

Interpretation-the chemical, acetic acid causes the hydra to eject nematoycysts.

For this investigation refer the student to "A Sourcebook for Biological Sciences", by Morholt, et. al.

Activity C

1. Observation - as the light to the eye increases the pupil contracts.

Interpretation-light causes the size of a pupil to change.

New Problem - Why are some animals able "to see in the dark"?

Refer student to article in "Science World", Volume #20, Issue 5, March 2, 1970.

2 and 3. Activity has not been tried and can only speculate as to possible observations.

4. Observation - in a lighted room the planaria swim under the pebbles. In a darkened room with a light source below the petri dish the planaria swim into the shadow created by the pebbles.

   Interpretation-planaria swim from light.

Activity D

1. Observation - the frog moves and jumps when touched. Students jump when touched.

   Interpretation -organisms react to a touch

2. Observation -the tendril of the climbing plant curled around the twig

   Interpretation -the climbing plants curl their tendrils around objects that they come in contact with.

3. Observation -the miniosa leaves and stems wither and droop when touched. The sundew plants close when touched.

   Interpretation -plants respond when touched.

4. Same as three.

5. Same as one.

Activity E

1. Activity has not been done.

2. Observation -the paramecia collect near the surface of the liquid.

   Interpretation -paramecia respond to gravity.

There are several activities on Geotropism in "A Sourcebook for Biological Sciences".

Activity F

1, 2, 3, 4. Animals respond to sound.

At the end of these activities the students' attention may be directed towards several of the subconcepts. Also the students should be asked to give a summary statement of six types of stimulus to which organisms respond.

Design for Collection of Data

In the background information the student was given the opportunity of choosing an activity from several investigations, now we wish him to have the opportunity not only to select the stimulus he wishes to investigate but also the organism he will use. Once again the instructor should approve each project design before the student may proceed with the activity.

While students are working they frequently neglect to keep complete records. The projects that will follow in this section is not only an opportunity to reinforce the student's ability to design a useful experiment but also it is an opportunity to allow the instructor to teach proper record keeping and the reasons for it.

Questions

The suggested answers given below may not be complete. We would encourage each teacher to keep a record of answers they find and those submitted by students, compile the information and pass on to your science coordinator, who, in turn will give it to the Life Science Committee. This information, together with your comments and criticisms may be used to redraft a more pertinent and useful resource booklet.

1. The biotic and abiotic factors of the environment provide a complex variety of stimuli to which organisms respond.

2. The sense of touch. There are several specialized types of touch receptors, each of which may place a slightly different role in making the organism aware of the stimulus.

3. No, plants generally do not respond to sound, to touch, and their reactions to other stimuli is much slower than that of animals. E.g., a plant will not react to a loud voice or sound. However, some recent research shows some evidence that plants do react to a continuing noise.

6. Organisms generally respond to stimuli in a way that will ensure their urvival. Their response is usually based on instinct. However, some nimals appear to respond on the basis of "emotion" and may endanger their fe. For organisms that receive stimuli that present no threat to them ey may respond in a manner that helps bring about more comfortable ving for themselves.

7. rve tissues carry the stimulus from the external receptors of an nimal to some specific area of the body, usually called a brain, here the message is interpreted and a response message is sent back from the brain along the nerve cords to specific muscles in the animal. This is not the mechanism for response amongst plants.

8. Organisms do not respond to all stimuli from the environment because there are too many stimuli to be able to perform this job. Much of the stimulation from the environment is ignored by the organism because a response would serve no useful purpose to that stimulation. (Insist that students support answers with specific examples.)

9. An organism may react to several stimuli with one rsponse. A zebra may smell danger, hear the grass rustle, and see movement, and respond by running from the source of the stimuli. However, in a situation of less stress and of choice that organism will respond to the stimulus which is most directly related to its survival or comfort.

10. No. (Insist that students give several examples).

11. Organisms, at least animals, respond to internal stimulation; an empty stomach brings a response of looking for food providing another stimulation more directly associated with survival is not detected by the animal

12. Adjustments to climate and weather conditions.

Open-Endedness

1. The water in the cells of the animals would freeze and expand. The expansion may destroy some of the material in the cell or rupture the cell causing its death.

2. a) short term - panting, perspiring, dilation of surface blood vessels, decreased activity
   long term - shed hair, thinning of blood

   b) short term - perspiring, dilation of surface blood vessels, decreased activity
   long term - thinning of blood

   c) short term - increased respiratory rate, seed shade
   long term -

3. Warm-blooded animals have a constant or near constant body temperature regardless of weather and climate changes. The temperature of cold-blooded animals varies with the temperature of their environment.
4. If the number of light hours a plant receives is reduced it will flower more quickly than if it is exposed to a longer number of light hours.

TEACHERS' NOTES FOR INVESTIGATIONS 2 - 11

Investigation 2 (Source: Exploring Life Science, page 210)

Concept
Living organisms take in oxygen from their environment.

Problem
Most students will understand that living things require oxygen but they will not necessarily have performed an investigation to demonstrate this.

Background Information
Some of the background information may be gathered by performing simple experiments to show how a burning candle behaves in normal air. Students should understand thoroughly that the oxygen can be taken from the air or from water (from dissolved air in the water).

Observations
Students will note that the candle goes out sooner as a person holds his breath for longer periods of time before exhaling into the water-filled jar.

Organizing Data
Make sure the students are familiar with the two variables. The independent variable is the time air is held in the lungs.

Interpreting Data
1. It had the greatest amount of oxygen in the air around it.
2. More and more oxygen was removed from the air in the lungs.
3. Oxygen

Investigation 3 (Source: Exploring Life Science, pages 212, 214, 236)

Concept
Living organisms give off carbon dioxide.

Background Information
Possibly teacher or group demonstrations will help familiarize the students with the tests for carbon dioxide if they haven't as yet used them.

Observations
The change in color from blue to yellow (or yellowish-green) should suggest that carbon dioxide is given off. The exhaled air would also contain oxygen, nitrogen and other gases but these would not be produced as a result of respiration.

Interpreting Data
1. Respiration in living organisms results in the production of the waste product, carbon dioxide
2. Carbonic acid

Investigation 4 (Source: *Exploring Life Science*, pages 220-222)

Concept

Breathing is the process by which air (from the environment) enters and leaves an organ in which oxygen and carbon dioxide are exchanged.

Background Information

Students should have a good knowledge of the main structures of the human respiratory system before starting this investigation. This will help them understand the similarities between the model and the actual system in man. Most science reference books have sections on the respiratory system.

Design

If a bell jar is not available, a gallon jug with the bottom removed will do a good job. (See the *Sourcebook for the Biological Sciences* for instructions on how to remove the bottom.)

Observations

As the rubber membrane is pulled down, the pressure inside the jar increases. As a result, the pressure around the outside of the balloons is less than the pressure inside the balloons. This pressure difference causes the balloons to bulge. When the rubber membrane is pushed upward, the pressure in the jar increases, causing the balloons to collapse.

1. They expanded
2. Inhalation
3. Contracted
4. Exhalation
5. Space is increased, space is decreased

Interpreting Data

1. Pressure around them was decreased.
2. Pressure around them was increased.
3. See *Living Things*, pages 322-323

Investigation 5 (Source: Exploring Life Science, page 225)

Concept

The rate at which living organisms exchange oxygen and carbon dioxide is affected by many factors.

Prediction

Students should be encouraged to formulate their own prediction and hypothesis based upon their own experiences.

Design

A plastic gallon or half-gallon jug may be used in place of a glass jar. The outside of the jug should be marked off in cups. Make sure that students hold their noses closed when exhaling into the jug. This will prevent shallow breaths being taken.

Organizing Data

To determine the volume of air inhaled per minute, multiply the number of breaths per minute by the volume (in cups) of a breath. After heavy exercise, the rate of air interchange should increase between 10 and 20 times.

Interpreting Data

1. Exercise is one factor which affects breathing rate.
2. When sleeping. Because muscular activity is at a minimum at this time.
3. When running. Because muscular activity is at a maximum at this time.

Investigation 6 (Source: Exploring Life Science, page 216)

Concept

The breathing organs of some aquatic animals are adapted for taking oxygen from the air dissolved in water.

Observations

1. Seventeen pairs
2. They are attached to the legs and the maxillipeds.

Interpreting Data

1. Gills remove oxygen from the air dissolved in water.
2. Swallowing movements allow the water to pass over the gills so that the oxygen can be absorbed.

Investigation 7 (Source: Exploring Life Science, page 216)

Concept

Oxygen passes into the blood and carbon dioxide passes out of the blood by means of diffusion through membranes.

Background Information

A review of the main structures of the lung (as covered in Investigation 4) would help students develop a better understanding of the function of the air sacs in the lungs. If possible, a dissected lung could be used.

Design

If bromothymol blue is not available, limewater may be used. The color change should be noticeable after 15 to 20 minutes.

Interpreting Data

1. Carbon dioxide passed out of the balloon and into the water.
2. Carbon dioxide
3. Diffusion

Further Evidence

Diffusion of gases through membranes occurs not only in the breathing organs of living organisms but also in all the cells which compose their bodies.

Investigation 8 (Source: Exploring Life Science, page 237)

Concept
When blood absorbs oxygen it becomes frothy and turns a brilliant red color; when it contains large amounts of carbon dioxide it turns a dark red color.

Background Information
The filmstrip and microslide mentioned in Investigation #9 may be used for background information. Students could also study prepared microscope slides of the blood. Blood typing might also be done.

Observations
1. It turned a brilliant red
2. Became frothy
3. Should be a brighter red
4. It turned a darker red

Interpreting Data
1. Turns it frothy and bright red in color
2. Turns it darker red in color
3. Red blood cells
4. Haemoglobin in the red blood cells united with the oxygen.
5. In the capillaries in the lungs
6. (a) Arteries (b) Veins

Investigation 9 (Source: Life, Its Forms and Changes, page 119)

Concept
Blood vessels are adapted by structure for the function of transporting oxygen to the cells and carbon dioxide away from the cells.

Background Information
Filmstrips such as the Life Processes of Man (available from the Audio-Visual Services Branch) may be used very effectively to provide the necessary background information for this investigation. If your school has microslide viewers and microslides, set #68 will prove very valuable.

Design
The webbed foot of a frog may be used in place of a goldfish tail fin. Since the goldfish cannot be kept in the cotton for too long a period of time, it may be worthwhile to use a microprojector instead of a microscope. Make sure the students know exactly what to look for before proceeding.

Observations
1. Numerous
2. Different sizes, different rates of blood flow
3. No
4. Arteries
5. Movement of materials in and out of the blood occurs only in capillaries
6. Yes
7. Yes
8. Capillaries
9. Refer to Life, Its Forms and Changes, page 118

Interpreting Data
1. Very rapid
2. Artery carries blood away from the heart; a vein carries blood back to the heart.
3. Artery has much thicker walls
4. Very thin-walled (one layer thick)
5. See #5 under observations above
6. In capillaries

Investigation 10 (Source: Modern Life Science, page 17-18)

Concept
In cold-blooded animals the rate at which the blood circulates depends upon the temperature of the environment.

Design
A microprojector may be used instead of a microscope in the investigation with Daphnia. In this way everyone in the group can observe the heartbeat.

Observations
In both instances (the earthworm and the water flea) the contractions per minute will increase with an increase in temperature and decrease with a decrease in temperature.
1. There should be some variation in the rate of blood vessel contractions because of differences in the earthworm.
2. Answers will vary.
3. Every measurement may vary slightly from every other one. The average of several trials usually gives the best results.
4. The average obtained by the class. The greater the number of trials, the more accurate the average.

Graphing Data
Independent variable is the temperature. Dependent variable is the number of heartbeats.

Interpreting Data
1. Rate of heartbeat slowed down
2. Rate of heartbeat increased
3. At higher temperatures there is a greater exchange of gases between the blood and the cells than at lower temperatures.
4. At higher temperatures because they are more active and therefore require more oxygen.
5. During hibernation, the amount of oxygen required is very low. Therefore, circulation of the blood is very slow.

Investigation 11 (Source: Exploring Life Science, page 230)

Concept
Muscular activity affects the rate at which the blood circulates.

Design
To facilitate the counting of the pulse rate, intervals of 15 seconds should be used instead of 60 second intervals.

Observations
The pulse rate should be the lowest when resting, increase while standing and be the highest after exercise.

Organizing Data
1. The highest rate should be around 140.
2. The lowest rate may be around 50.
3. The range from lowest to highest could be near 100.
4. Resting 50-85; standing 55-90; after exercise 120-150.

Interpreting Data
1. Muscular activity increases the rate because more oxygen is required by each muscle cell to produce energy by oxidation.
2. When sleeping. Muscular activity would be at a minimum.
3. Rapid exchange of oxygen and carbon dioxide between blood capillaries and muscle cells.
4. The accumulated carbon dioxide and nitrogenous wastes must be removed from the cells as quickly as possible. For this reason the blood must continue to circulate rapidly for a short time after the exercising stops.

Investigation 12 (Source: Exploring Life Science, page 382, 371, 383-5, 399)

Concept
Leaves are adapted by structure for the function of photosynthesis.

Design
It may be worthwhile to prepare several collodian casts of the undersurface of a leaf to show the stomata and surrounding guard cells. These casts, mounted on slides, could be used by students who have difficulty in preparing good specimens.

Observations
1. Yes
2. Flat - rectangular
3. If the leaf was in bright sunlight prior to being prepared, there may be two or more rows of pallisade cells.
4. Chloroplasts
5. The pallisade cells are more compact, with very few air spaces between them.
6. The pallisade layer. This indicates that more food is produced in this region of the leaf than in other regions.
7. Air spaces (including carbon dioxide) and water storage.

9. Thick-walled xylem tubes and thin-walled phloem tubes
10. Diagram

11. Stomata (stomates)
12. Guard cells
13. Answers will vary depending upon the type of leaf used.
14. They contain chloroplasts
15. Diagram

Interpreting Data

1. No. Only the pallisade and spongy layers and the guard cells in the lower epidermis.
2. Concentration of chlorophyll in chloroplasts in pallisade layer near upper surface.
3. To permit light to reach the chloroplasts.
4. To keep evaporation of water to a minimum.
5. Transport water and dissolved minerals to the leaf cells and manufactured food (sugar) away from the leaf cells.

Investigation 13 (Source: Investigating Living Things, pages 83-84)

Concept

The green substance found in the cells of green plants in chlorophyll.

Design

The best results will be obtained with spinach leaves. If these are not available, beet leaves will give satisfactory results.

Observations

1. It is settled into layers of different colors.
2. Two layers
3. The upper layers
4. Yellow, red, orange

Interpreting Data

1. No. It may be found in non-green leaves because it is being masked by the other pigments in the leaves.
2. They do contain some chlorophyll.
3. The chlorophyll in the leaves breaks down and the other pigments show up.
4. Some leaves contain more chlorophyll than others.
   The chlorophyll in some leaves is darker green than in other leaves.

Investigation 14 (Source: Investigations of Cells and Organisms, pages 60-61)

Concept

Chlorophyll requires the energy provided by light in order to manufacture food.

Background Information

The following audio-visual aids may be used very effectively to introduce and provide the necessary background for all the investigations which deal with photosynthesis:

From IMC - Films: #F451-8C-0 Photosynthesis and the Respiration Cycle
#F100-8C-0 Growth of Plants
Model: #M9 Leaf Section
From AVSB - Filmstrips: #4004 How Plants Make Food and Respire
#3365 Green Plants - Food Factories of the World

If you have microslides in your school, set #59 on Photosynthesis will be very useful. Check with the latest edition of the IMC catalogue for any new audio-visual aids (including 8 mm loops).

Design

The best results will be obtained where the leaves are exposed to very bright sunlight. A considerable amount of time may have to be spent in removing the chlorophyll from the leaf. The whiter the leaf, the more pronounced the results when the iodine test is used.

Observations

1. The leaf from the light will turn blue-black, revealing the presence of starch. The covered leaf will remain unchanged or darken only slightly.
2. The leaf exposed to light. It turned blue-black.

Interpreting Data

1. Light provides the energy by which the chlorophyll combines carbon, oxygen and hydrogen to form carbohydrates.
2. See the background information in the student's notes.

Further Evidence

1. Only part of the leaf would have turned blue-black.
2. The deeper parts of the ocean do not receive sunlight and therefore plants cannot make food in these regions.

New Problems

If time permits, a variety of other investigations could be carried out to provide more insight into the role of light in the food-making process. Possibly each group in the class could be assigned a different problem to investigate and then report their findings to the whole class.

Investigation 15 (Source: Investigations of Cells and Organisms, page 66-67,
Exploring Life Science, page 389,
The Biological Sciences, pages 51-52 (Lab book))

Concept

Chlorophyll is necessary for the manufacture of carbohydrates in the chloroplasts of green cells.

Observations

1. The areas of the leaf which were green should show a blue-black color. The other areas will remain white.
2. See #1 above.
3. The areas should be almost identical.

Interpreting Data

1. Only certain parts contained chlorophyll.
2. No. Only in those parts containing chlorophyll. Cells without chlorophyll could not make food.
3. Yes. As a producer it depends entirely on its own chlorophyll for the production of food.

Investigation 16 (Source: Life, Its Forms and Changes, page 207, Exploring Life Science, page 390-391)

Concept

During photosynthesis green plants take in carbon dioxide and give off oxygen.

Background Information

This investigation provides an excellent opportunity to bring out the important ideas in the oxygen-carbon dioxide cycle as shown in a balanced aquarium. Furthermore, it can be used to illustrate the relationship between respiration and photosynthesis. Additional investigations may be used, either before or after this investigation to study various aspects of a balanced aquarium.

Observations

Design 1:
1. Turned blue
2. No.
3. Carbon dioxide was not removed - no plants there.

Design 2:
1. Leaf from plant A will remain white. Leaf from plant B will turn blue-black.
2. More starch in leaf B.
3. Not all the carbon dioxide was removed.
4. It had a rich supply of carbon dioxide so it could produce more food.

Design 3:
1. No. Only in test tube A.
2. It should glow more bright in A than in B.
3. Possibly the presence of carbon dioxide.
4. It should rise, providing evaporation was not a factor.

Interpreting Data

1. Carbon dioxide.
2. Water in test tubes C and D (placed in darkness) did not turn back to blue because carbon dioxide was not used up.
3. Oxygen.
4. In respiration, food and oxygen are combined to produce energy and carbon dioxide is given off. In photosynthesis, carbon dioxide and water are combined with the energy provided by light and food is produced while oxygen is given off. One is the exact opposite to the other.
5. No. Much of the oxygen is used by the cells in the plant for respiration.
6. A shortage of dissolved oxygen in the water. This could be caused by the lack of photosynthesis (or reduced rate of photosynthesis) by the plants in the aquarium.

Further Evidence and New Problems

Once again, there are numerous additional investigations which could be carried out by the entire class or by small groups or individuals in the class.

Investigation 17 (Source: Exploring Life Science, pages 371 and 390-1)

Concept

The exchange of gases between leaves and their external environment occurs through tiny pores called stomates.

Design

Part A:
1. If the leaf was actively producing food when it was removed from the plant, it would contain a high concentration of sugar and water which would move into the guard cells and cause them to become turgid or swollen. This would make the openings (stomates) between the guard cells larger. When the glucose solution is introduced, the water is drawn out of the guard cells and into the glucose solution. This causes the guard cells to lose their turgidity or swelling. As a result, the openings between them become smaller.
2. Without the glucose solution around them, the guard cells were swollen and had large stomata. With the glucose solution, they were contracted and had smaller stomata.
3. The surrounding cells must contain more water than the guard cells.
4. Chloroplasts.

Part B:
1. No. Leaf from plant B contained more starch.
2. It covered the stomata and therefore carbon dioxide could not reach the chloroplasts in the cells of the leaves.

Interpreting Data
1. Water is drawn into the guard cells.
2. Sausage shape. Higher.
3. When there is a concentration of water in the guard cells than in the surrounding cells and water moves out of the guard cells and into the surrounding cells.
4. By opening and closing and therefore, regulating the entry of carbon dioxide into the leaf.

Investigation 18 (Source: Investigating Living Things, pages 91-92
Exploring Life Science, page 379-380)

Concept

Raw materials needed for photosynthesis may be absorbed from the external environment by means of osmosis and transported to the food-making organs by means of capillarity.

Background Information

Considerable use should be made of the microscope in studying root and stem structures. Prepared slides, as well as student-made slides will help to give a more complete understanding of these two organs of a plant. In addition, filmstrips should provide a good source of basic information. Collections of various types of roots and stems (possibly obtained through field trips) should also be included.

Observations

Part A:
1. The level of the molasses in the glass tube rose while the level of the water in the beaker fell.
2. There was less water in the beaker. (The top of the beaker could be covered with plastic to prevent evaporation.)
3. It must have travelled through the cells of the carrot.
4. The molasses solution inside the carrot.
5. It continued to rise.

Part B:
1. Diagrams
2. Diagrams
3. The leaves should turn red

Part C:
1. Diagram
2. In the finest tube. In the widest tube.
3. In the widest tube. In the finest tube.

Interpreting Data

1. The absorption of water and minerals.
2. Root hairs.
3. Water moves through the membrane and into the root hair cells.
4. The molasses solution inside the carrot.
5. Xylem tubes (vascular bundles). Veins.
6. In concentric rings.
7. They are scattered throughout the pith.
8. A fibrovascular bundle containing phloem and xylem tubes.
9. a) Fine tubes (smallest diameter) b) Wide tubes (with largest diameter)

REFERENCES USED FOR RESPIRATION AND NUTRITION

* T - denotes teacher reference P - denotes pupil reference

P 1. Investigating Cells and Organisms, Abramoff and Thomson

T 2. BSCS Yellow Version - Text and Lab Book

P. 3. Life Science, Mason and Peters - Text and Lab Book

P. 4. Modern Biology, Moon, Mann, Otto - Text and Lab Book

P. 5. Living Things, Fitzpatrick, Bain, Teter - Text and Lab Book

P. 6. The Biological Sciences, Frazier, Smith - Text and Lab Book

P. 7. Principles of Science, Book 1, Heimler and Neal

P. 8. Investigations in Science, Cole and Saxton

P. 9. Exploring Life Science, Thurber - Text and Lab Book

P. 10. World of Living Things, Brandwein - Text and Lab Book

P. 11. Life: Its Forms and Changes, Brandwein - Text and Lab Book

P. 12. Methods of Science, Book 3, Brackenborough, Erwin, Rist and Wooster

T. 13. Living Things, NSTA

P. 14. Modern Life Science, Fitzpatrick, Hole

T. 15. BSCS Green Version

T. 16. A Sourcebook for the Biological Sciences, Morholt, Brandwein and Joseph

LIFE PROCESSES: STUDENT'S NOTES

Investigation 1

Problem
How do living things respond to stimuli?

Operational Definition
What is stimulus? (To answer this question observe the instructor's demonstration and then formulate an operational definition.)

Background Information
What are the different stimuli to which living things respond?

In order to answer this question your group will select one of the activities, A to [illegible], listed below and prepare a report that will be given to the class. As there are many things that should be done to determine an accurate and complete answer for the problem, it is necessary for the groups to work on different reports. But remember, you must do your work so that it is neat, careful, and complete, and you must report in a clear and easily understood way, so that every other student in the room may learn new facts from the things you have done. You are the scientist with your particular job to do in an attempt to help your classmates learn more about the answer to the question asked in the background information.

Following your selection of an activity you are to check with the instructor to ensure that one group is working on each of them. If an activity is not voluntarily selected a group will be assigned to it. Do not start working until you have explained to the instructor exactly what you are going to do.

For each activity that is listed the following things must be done and answered.

Make a neat record of your observations.
(The observations will be the organisms response.)

Describe what caused the response. (The description will be of the stimulus that caused the response that you observed.)

Activity A

1. Place a frog or a toad in a jar and suspend a thermometer inside the jar so that the bulb is approximately one-half inch from the bottom. Count the movement of the frogs throat as it breathes and record the temperature in the jar. Place the jar in a dish of ice and at regular intervals count the movement in the frogs throat and record the temperature. Place the jar in water baths at temperature above that of the room. Record throat movement and temperature. Make a chart of your observations, first on a sheet of rough paper and later in an organized fashion to be used as part of your notes and as a report to the class.

2. Place a guppy or some of the small fish found in local streams in a small aquarium. Count the gill movements and record the water temperature. Repeat the measurements at different temperatures using a heat lamp to increase the temperature of the water and adding snow or ice cubes to cool the water. Chart your results.

3. Place a diving beetle in a jar and suspend a thermometer in the jar. Put a rock at the bottom of the jar. Record the number of times per minute the bug comes to the surface at different temperatures.

4. Prepare 200 ml of yeast infusion by dissolving ½ package yeast in water and 200 ml of sugar solution by dissolving 4 sugar cubes in water. Fill half of a test tube with yeast infusion and the other half with sugar solution; seal the tube with a one-hole stopper. Invert the test tube into an ice bath, record the time to collect a half a test tube of gas and the temperature of the bath. Try other temperatures. Make a graph of your results.

5. Cricket Chirp Rate on a Summer Night.

Temp. °C	26	25.5	23	20	19	18	13	10
Chirps per sec.	1.94	1.93	1.76	1.50	1.40	1.36	.94	.58

Graph the results.

Activity B

1. Place three or four planaria in a petri of pond water and observe their movements. Place a drop of ammonium hydroxide (NH_4OH) near the planaria and observe their behavior.

2. Very carefully place a small sprig of vegetation into a well slide, attached to which there is a hydra. Allow the slide to sit undisturbed on the microscope stage for a few minutes. Turn on the substage light and observe the animal. Now place a drop of WEAK acetic acid (CH_3OOH) into the depression, making certain that you are watching the hydra the full time that you are placing the drop in the well slide.

Activity C

1. Stand in front of a mirror in a darkened room for two minutes. Turn on the lights and observe the pupils of your eyes. Take a dog, cat, mouse, or other animal into a dark room for a few minutes, then turn on the lights and observe their pupils.

2. Place a given number of fruit flies or moths into a long narrow transparent container (glass or plastic tube) that has been covered with black paper alone one-half of this length. Place the container in a completely dark drawer or room for ten to fifteen minutes. Open the drawer or turn on the light and quickly count the number of animals you can see in the tube. (Start the counting at the centre of the tube and move towards one end.) Turn off the light to darken the room and repeat again in five minutes. Do this several times and determine the average number of visible animals.

   Place the tube in a darkened room for another five minutes and then turn on the lights. Count the number of animals visible and record. Count the number visible thirty seconds later and record. Repeat the count each thirty seconds for five minutes. Record all results in a chart and draw a graph.

3. Repeat design two above by first filling the tube with water and then placing water animals in it as planaria, snails, daphnia, fish, diving beetles, etc. For the slow moving water animals you should use a much shorter tube and give them more time to complete their movements.

4. Place three or four planaria in a culture dish of pond water with a few pebbles at the bottom. Observe the planaria until all activity has ceased and then darken the room. Turn on a light source beneath the culture dish and note the behavior of the planarians.

Activity D

1. In a quiet room by yourself gently remove a frog or toad from a terrarium and place on a table. Move very slowly so that you will not frighten the animal. When you place the animal on the table put your hand directly behind the animal so you can touch it with a small movement of your forefinger. After sitting quietly for two or three minutes gently touch the animal with your forefinger, without moving the rest of your body and record your observations. Next walk up behind one of your friends when they do not know you are present. Make certain they are not doing work that presents a potentially dangerous situation or can result in damage to something and then gently touch them on the back of the neck.

2. Touch a small stick to the tendril of ivy or pea plants. Record what happens after an hours time. Try several tendrils.

3. With forceps gently pinch the top of the leaflets of a miniosa or sundew plant. What happens.

4. With a probe touch the interval structures of a venus fly trap. What happens?

5. With a probe touch a hydra, leech, planaria, or eathworm. What happens.

Activity E

1. Place some land snails at the bottom of a tall container and observe their activity.

2. Pour a thick culture of paramecium into a test tube and stopper it. Let it sit quietly for a while and observe the location of the paramecium.

Activity F

1. Come up beside a sleeping animal or one that is unaware of your presence and clap your hand once loudly. Record your observation.

2. Observe the movements of fish in an aquarium. Then pound the table once with your fist and observe the behavior of the fish.

3. Observe the behavior of your dog when someone first approaches the outside of your home.

4. Very quietly creep up to a pond, or slough and record what happens to the night sounds made by the pond dweller.

As each person describes what he had done for an activity make a list of the different stimuli to which living organisms respond.

Design for Collection of Data

In background information you had the opportunity to perform a simple activity described there. Now we want you to describe and perform an activity which will help you to answer the problem given at the start of Lab Activity 3-1. Your activity cannot be the same as any of those described in this experiment, it must be your own idea or another idea that you seen or read about elsewhere. Before doing any part of the design you must have it approved by your instructor. Remember to limit your design to one of the stimuli we have discussed and to the living organisms that are available to you at this time. Once again you will have to report your activities to the total class so that they may learn additional information about the problem.

Observations

Keep a record of what you observe as you perform your experiment.

Interpretation of Data

1. Present your findings of the stimulus you investigated to the class.

2. Keep your own summary of the findings of others as they report to the class.

Questions

1. In nature what normally provides the stimulus to which an organism responds?

2. What senses let you know that you are sitting in a draft?

3. Do plants respond to all the stimuli that animals do? Support your answer with evidence.

4. In the chart below you are to identify the receptors (organs of the body) that allow the animals in the list to detect the stimuli written across the top of the chart.

Stimuli						
Hydra						
Insect						
Earthworm						
Snake						
Frog						
Fish						
Mouse						
Plant						

5. Some animals and plants have highly specialized stimuli receptors. Try and identify as many of them as you can and complete the chart below.

Organisms	Receptor	Special function of a receptor and reason why organisms developed such a specialized receptor

6. Why do organisms respond the way they do to the different stimuli?

7. What might allow the stimuli to bring about a response? (What are the interacting components between the stimulus and response)?

8. Do organisms respond to all stimuli presented by the environment? Give supporting evidence.

9. Why do organisms react or select certain stimuli over others?

10. Do all organisms respond to the same stimuli in the same manner?

11. The stimuli response situations we have discussed are external stimuli. Do organisms respond to interval stimuli? Explain.

12. Up to this point in the investigation we have been looking at short term responses or organisms. For a short term response the organisms makes a rapid adjustment to the stimuli. Can you list some long term responses an organism may exhibit in order to survive in its environment?

Open-Endedness

1. Most cells contain about 75% water. Explain what may happen as the cells were exposed to temperatures below the freezing point of water.

2. Describe how the following organisms adjust to very hot weather.
   a. dog
   b. man
   c. frog

3. What do we mean by:
   a. warm-blooded animals
   b. cold-blooded animals

4. What stimulus might bring about the flowering process in a plant?

5. Make an insect-proof cardboard box about two feet long. Place a light source inside at one end and a horizontal slit one inch by six inches at the other end. Leave the box out at night, with the light on for one hour.

Examine the eyes of the insect in the box and compare them with the eyes of insects that are active during the day. Write a report of your comparisons.

Investigation 2

Problem

To show that living organisms take in oxygen from the air in their environment.

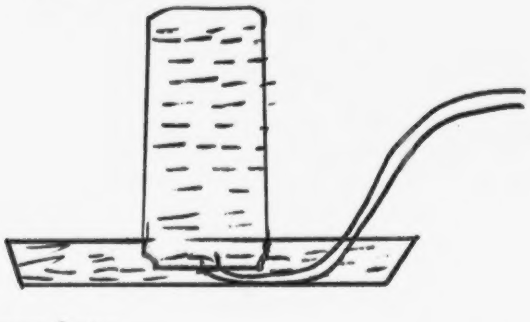
Background Information

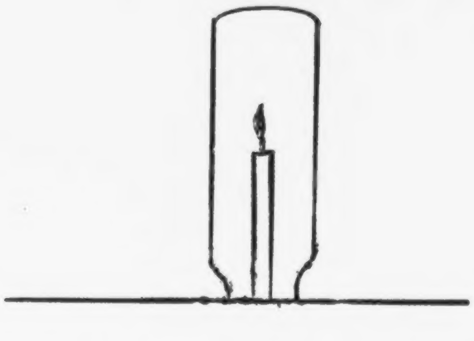
1. What gases are found in the air in the atmosphere or in the air dissolved in water?
2. What gases are found in exhaled air?
3. What gas is consumed by a candle when it burns?

Design for Collection of Data

Apparatus - Glass jar, trough, rubber tube, candle, water, matches

1. Turn the glass jar upside down over a burning candle. Measure the time the candle burns (in seconds).
2. Fill the same jar with water and turn it upside down in the pan of water.
3. Place one end of the rubber tube into the jar.
4. Take a deep breath, hold it 30 seconds, and then blow it into the jar.
5. Lift the jar out of the water and quickly set it over the burning candle. Measure the time the candle burns.
6. Repeat the same procedure, but hold the air in the lungs for different periods of time (according to the times given in the table below).





Procedure

Use the space below to record any changes (additions or deletions) to the above design.

Observations

Trial	Time Air Held in Lungs	Time Candle Burns
1	0 seconds	....
2	0	....
1	15	....
2	15	....
1	30	....
2	30	....
1	45	....
2	45	....
1	60	....
2	60	....

Organizing Data

Compare time air was held in the lungs with the burning time. What are the two variables?

Graphing Data

Construct a line graph to show the comparison between time in lungs and burning time.

Interpreting Data

1. Why did the candle burn the longest time when it was placed in air which was not in the lungs at all?

2. Why did the burning time of the candle go down as the air was held in the lungs for longer and longer periods of time.

3. What gas was being removed from the air in the lungs?

New Problems

1. What factor, other than the shortage of oxygen, could affect the burning time of the candle?

2. Would the size of the body or the sex of the person affect the burning time of the candle?

3. Would the knowledge gained from this investigation be useful in artificial respiration (mouth-to-mouth resuscitation)?

4. How is the intake of oxygen affected when the air contains carbon monoxide?

Investigation 3

Problem

To show that living organisms give off carbon dioxide to their environment.

Background Information

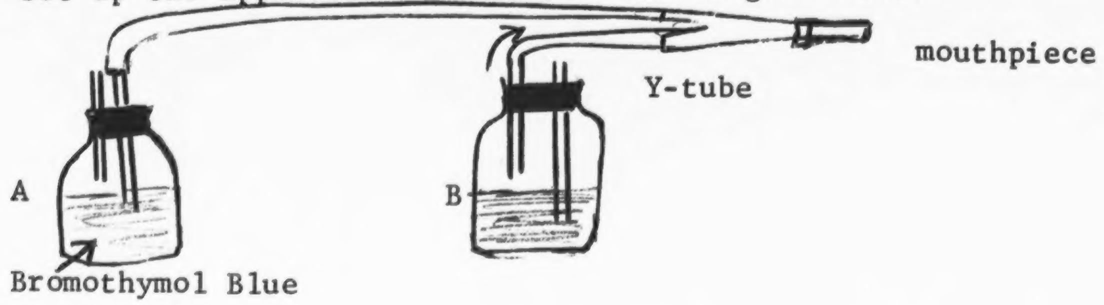
1. What is meant by the "acidity" of a solution?
2. What is a basic solution?
3. What is an acidic solution?
4. How does carbon dioxide affect a solution when it dissolves in it?
5. How is limewater used for testing for the presence of carbon dioxide?
6. How is bromothymol blue used for testing for the presence of carbon dioxide?

Design for Collection of Data

Design One

Apparatus - 2 jars, 2-2hole stoppers, rubber tubing, y-tube, glass tubing, bromothymol blue solution.

1. Set up the apparatus as shown in the diagram below

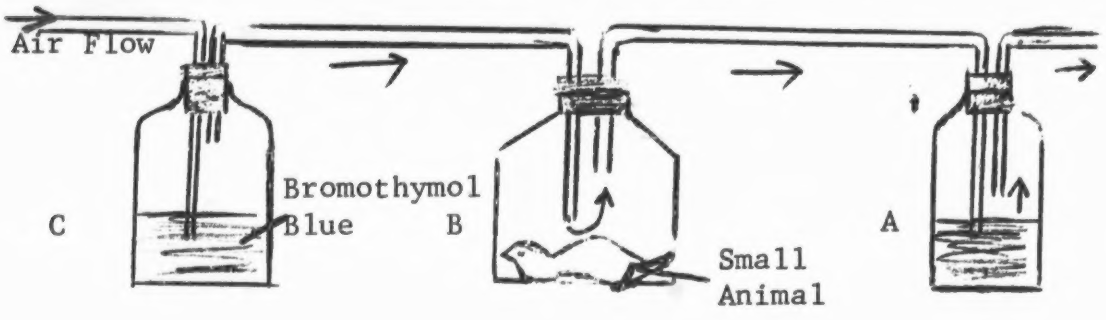


2. Taking normal breaths of air, SLOWLY inhale and exhale through the mouthpiece. (You must inhale and exhale slowly. Heavy breathing will force the solution out of the open tubes)
3. Continue inhaling and exhaling until you notice a change in the color of the solution in either jar.
4. What is the purpose of Jar B?

Design Two

Apparatus - 2 small jars, 1 large jar, glass tubing, small animal, bromothymol blue solution or limewater

1. Set up the apparatus as shown in the diagram below:



2. Place the small animal in the large jar (B) and force air through the apparatus. Watch for changes in the color of the solution in jar A and jar C.

3. What is the purpose of jar C?

Design Three

Apparatus - goldfish, glass container to hold goldfish comfortably, bromothymol blue solution, aquarium water

1. Add enough bromothymol blue to a container of aquarium water to give it a light blue color.

2. Place the goldfish in the container and close it.

3. Observe the color of the water over a period of an hour. (Remove the goldfish and return it to the aquarium as soon as you are finished with your observations.)

Procedure

Use the space below to record any changes in the above design.

Observations

Carefully record your observations for each of the designs.

Interpreting Data

1. If we assume that the color change in all three cases was due to carbon dioxide, what general statement can we give about the living things tested?
2. What acid was formed when the carbon dioxide dissolved in the water?

New Problems

1. How does temperature affect the production of CO_2?

2. Do warm-blooded animals give off carbon dioxide at the same rate as cold-blooded animals?

3. What structures are involved with the intake of oxygen and the giving off of carbon dioxide in man?

4. How could the bromothymol blue be turned back to blue again?

Investigation 4

Problem

To investigate the process by which oxygen enters and carbon dioxide leaves the respiratory system of man.

Background Information

Your background research should provide information about the following: (include neatly labelled diagrams)

1. the difference between breathing and respiration
2. the two phases in breathing
3. the chief breathing organs and their functions

Design for Collection of Data

Apparatus - bell jar or gallon jug, y-tube, 1-hole stopper, 2 balloons, rubber sheeting, string.

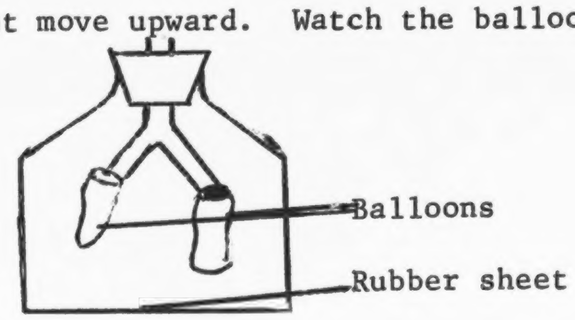
1. Insert the Y-tube into the rubber stopper and then insert the stopper into the neck of the jar. What does the Y-tube represent?

2. Tie the balloons securely on the two arms of the Y-tube. What do the balloons represent?

3. Over the open base of the jar, stretch the rubber sheeting and tie it firmly. What does the bell jar represent? What does the rubber sheet represent?

4. Grasp the center of the rubber sheet from beneath and pull it downward. Watch the balloons.

5. Let the rubber sheet move upward. Watch the balloons.



Procedure

Record any changes in procedure in the space below.

Observations

1. How did the balloons behave when the rubber sheet was pulled down?
2. What phase of breathing did this represent?
3. How did the balloons behave when the rubber sheet moved upward?
4. What phase of breathing did this represent?
5. What happens to the amount of space inside the jar when the rubber sheet is pulled down? Is pushed up?

Interpreting Data

1. Why did the balloons fill with air when the rubber sheet was pulled down?

2. Why did the balloons collapse when the rubber sheet was pushed up?

3. Write a short paragraph explaining how the lungs and diaphragm operate in the breathing process.

Operational Definition

Define breathing.

New Problems

1. What function is performed by the ribs in the breathing process?

2. Why must an "iron" lung be used on people who have poliomyelitis?

3. What factors affect the rate of breathing?

Application

How does artificial respiration work?

Investigation 5

Problem
What affects the rate at which breathing takes place?

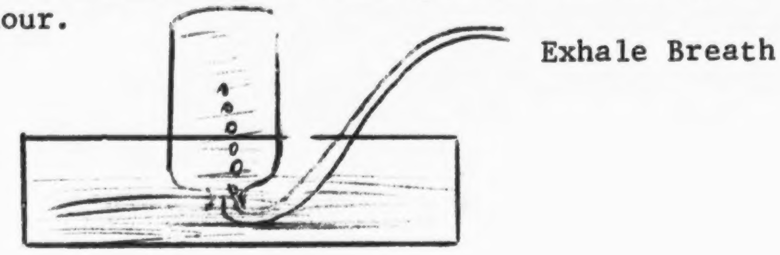
Prediction

Hypothesis

Design for Collection of Data

Apparatus - empty aquarium, rubber hose, gallon jug (marked off in cups)

1. Count the number of breaths you take (the number of times you inhale) while breathing normally.
2. Exhale one normal breath into the gallon jug and measure its volume in cups, using the scale on the jug. WHILE EXHALING, HOLD YOUR NOSE WITH YOUR FINGERS.
3. Calculate the amount of air that passes through your lungs per minute. Then per hour.
4. Do some heavy exercise for 2 - 3 minutes. Then exhale a breath into the galloon jug and measure its volume in cups. Once again, make sure your nose is closed.
5. Calculate the amount of air that passes through your lungs per minute. Then per hour.



Procedure
Record any changes in the above design.

Observations
Normal breathing rate is ______ breaths per minute.

Normal Breath	Volume in Cups	
Trial 1	______	
Trial 2	______	
Trial 3	______	Average ______

Breath After Exercise	Volume in Cups	
Trial 1	______	
Trial 2	______	
Trial 3	______	Average ______

Organizing Data

1. Calculate the air interchange per minute during normal breaths. Then per hour.

2. Calculate the air interchange per minute during heavy exercise. Then per hour.

3. How does the normal rate compare with the rate after heavy exercise?

Interpreting Data

1. What is one factor which affects the rate of air interchange (rate of breathing)?

2. When might the rate of air interchange be at its lowest? Why?

3. When might the rate of air interchange be at its highest? Why?

New Problems

1. Why does the breathing rate increase with increased muscular activity?

2. What factors other than exercise might affect the rate of breathing?

Investigation 6

Problem

To investigate the breathing structures and the breathing process in aquatic animals.

Background Information

Your background research should provide information on the following: (including labelled diagrams)

1. The chief breathing organs of the fish.
2. Why fish have gills rather than lungs.
3. The movement of water in the breathing process.

Design for Collection of Data

Design One

Apparatus - preserved crayfish, dissecting set, dissecting pan, watch glass, scissors

1. With the scissors, cut along the mid-line of the dorsal surface of the carapace from the posterior end up to the groove that divides the head from the thorax.
2. Make a cut along the cervical groove from its outer extremity up to the first cut.
3. With forceps, lift off the section of the carapace.
4. Examine the gill structure carefully and observe the number, position, and arrangement of the gills.
5. Remove some of the gills, either by cutting them at their base or by removing a walking leg with the gills attached.
6. Float a gill in a watch glass of water. The water spreads the gill filaments apart and they may be observed more easily.

Design Two

Apparatus - large goldfish, small jar, piece of wire or fibreglass screening, strong thread or wire, medicine dropper, ink

1. Cut the screening in a rectangular shape and fold it over to make a sleeve into which the fish will fit. Make sure the sleeve is shaped in such a way as to allow the fish to breathe normally but not to swim.
2. Crimp the two ends of the sleeve or fasten them together with a paper clip.
3. Trap the fish with a fishnet and carefully place it in the wire screen under the water.
4. Now, crimp or fasten together with top of the sleeve. Tie the thread or wire to the top of the sleeve.
5. Lower the fish and sleeve by the thread into the small jar. Make sure the temperature of the water in the jar is the same as that from which the fish was taken.
6. Allow the fish a few minutes to adjust to the new environment. Then put a small amount of ink into the water with the medicine dropper. Place it near the fish's mouth. Note what happens to the dye.
7. As soon as you have clearly noted the path of the dye or ink return the fish to the original aquarium.

Procedure

Record any changes in the above design.

Observations

1. How many gills does the crayfish have?

2. Where are the gills of the crayfish located?

3. To what parts of the body of the crayfish are the gills attached?

4. Make a sketch of a gill (crayfish).

5. Briefly describe the breathing process in fish.

Interpreting Data

1. What functions are performed by the gills of aquatic animals?

2. What is the purpose of the "swallowing" movements in fish?

New Problems

1. How do lungfish breathe?

2. How does oxygen enter the systems of animals which do not have either lungs or gills? (e.g., insects and worms).

Investigation 7

Problem

To investigate the exchange of gases in the lungs.

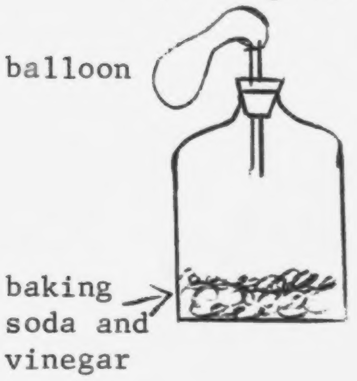
Background Information

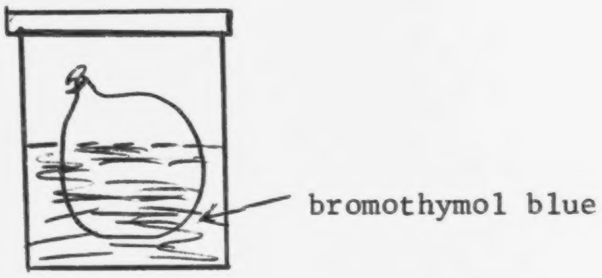
The bronchial tubes which enter the lungs divide again and again until there are millions of branches. The smallest of these branches end in clusters of 10 to 20 air sacs. The walls of the air sacs are covered with tiny blood vessels. Gases are exchanged between the air in the sacs and the blood in the vessels. Oxygen from the air is taken into the blood while carbon dioxide is taken out of the blood. Although this is a very slow process, there are so many air sacs that a plentiful supply of oxygen is provided for the body.

Design for Collection of Data

Apparatus - baking soda, small jar, one-hole stopper, glass tube, string, vinegar, bromothymol blue, large jar with lid

1. Blow up a balloon to stretch the rubber and then let the air out.
2. Attach the balloon to a glass tube in the stopper of the small jar as shown in the diagram below.
3. Pour vinegar into the bottle. Then add baking soda wrapped in a bit of tissue paper and insert the stopper.
4. When the balloon is full of carbon dioxide, tie its mouth and remove it from the glass tube.
5. Fill the large jar about one-third full of water. Add bromothymol blue to the water.
6. Place the balloon in the large jar so that at least half of it is in the water. Fasten the lid on the jar tightly. Observe the water over a period of an hour or so.





Procedure

Record any changes in procedure

Observations

What changes took place in the water?

Interpreting Data

1. What caused the water to change color?
2. Which molecules passed through the rubber?
3. What is the process called by which molecules pass through a membrane?

Further Evidence

At what other points in the body would oxygen and carbon dioxide pass through thin membranes.

Investigation 8

Problem

What effect does (a) oxygen and (b) carbon dioxide have on the blood?

Background Information

Your background research should provide information on the following:

1. the function of the blood
2. the composition of the blood
3. the function of the red corpuscles
4. the importance of haemoglobin

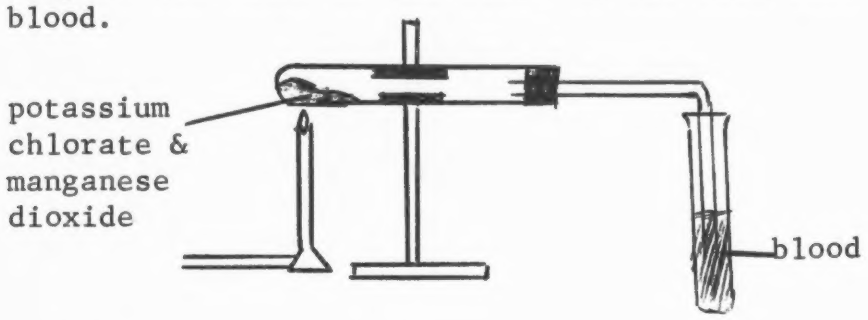
Prediction

Hypothesis

Design for Collection of Data

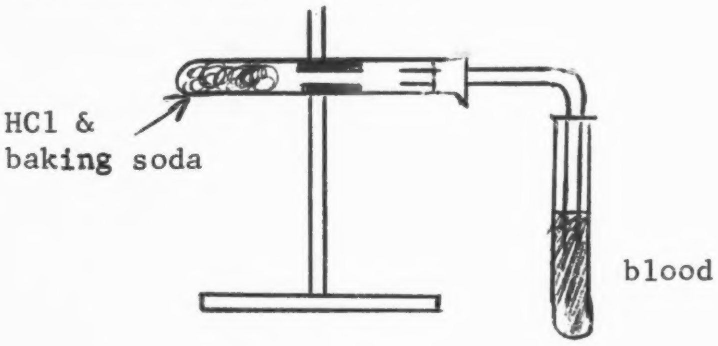
Apparatus - animal blood (from a slaughter house), potassium chlorate, manganese dioxide, dilute HCl, baking soda, 4 test tubes, 2 rubber stoppers

1. Put dry manganese dioxide and potassium chlorate in a test tube. Then fill a second test tube two-thirds full of fresh blood and set up the apparatus as shown below.
2. Heat the mixture and allow the generated oxygen to bubble through the blood for 3 to 5 minutes. Note carefully any color change.
3. Compare the color of the blood in the test tube with the original blood.



4. Put some baking soda into a test tube and slowly add dilute HCl until about half full. Set up the apparatus as shown below.

5. Bubble the generated carbon dioxide through the blood for a few minutes. Note any color change. Compare the color of the blood with the original blood.



Observations

1. What happened to the color of the blood when the oxygen was bubbled through it?

2. Did you notice any other change in the appearance of the oxygenated blood?

3. How did the oxygenated blood compare with the original blood?

4. What change was there in the color of the blood when the carbon dioxide was bubbled through it?

Interpreting Data

1. What effect does oxygen have on the blood?

2. What effect does carbon dioxide have on the blood?

3. Which blood cells were involved with oxygen and carbon dioxide?

4. What function did the haemoglobin perform?

5. Where would this reaction occur in the human body?

6. Which blood vessels would contain (a) oxygenated blood? (b) Deoxygenated blood?

New Problems

1. What is anemia?

2. Are all bloods red in color?

3. How does haemoglobin react to carbon monoxide which may be in the air along with oxygen?

Investigation 9

Problem

To investigate the circulation of blood through blood vessels.

Background Information

The blood performs two major functions in the respiration process. It absorbs oxygen from the breathing organs and circulates it to all of the cells in the body. Also, it collects carbon dioxide from all the cells and carries it to the breathing organ for removal from the body.

1. What functions do the red corpuscles perform?

2. Briefly describe the structure and function of each of the following blood vessels:

   a. arteries
   b. veins
   c. arterioles
   d. venules
   e. capillaries

3. Describe the structure and function of the valves in the blood vessels.

Design for Collection of Data

Apparatus - goldfish (living), dip net, cotton batting, petri dish, cover slip, microscope

1. Remove a small goldfish from the aquarium with a dip net.
2. Wrap the fish in dripping wet cotton. (Do not cover the mouth and tail.) Place it in the bottom half of a petri dish. (The fish may have to be anesthetized if it moves around too much.)
3. Place a coverslip over a thin section of the tail. Then move the dish around so that the fish's tail is over the hole in the stage.
4. Note the movement of blood through the blood vessels.

Procedure

Record any change in procedure.

Observations

1. Would you say the number of vessels is few or numerous?
2. What difference do you note in the blood vessels?
3. Does blood flow at the same speed in all blood vessels?
4. In which blood vessels would the blood flow in pulses?
5. The smallest blood vessels you see are the capillaries. They are just wide enough to permit the passage of a single file of blood cells. Why is this so?
6. Blood enters the capillaries from small arteries called arterioles. Trace a capillary back to an arteriole. Does the blood flow more rapidly in the arterioles than in the capillaries?

7. Follow a capillary in the direction in which the blood is flowing. It will join a slightly larger blood vessel called a venule. Does the blood flow faster in the venules than it does in the capillaries?

8. Which type of blood vessels seem to be most numerous, arterioles, venules or capillaries?

9. In the space below make a diagram to show each of the three blood vessels mentioned in number 8. Label all parts.

Interpreting Data

1. How would you describe the rate at which the blood flows through the circulatory system?
2. What is the chief difference between the function of an artery and the function of a vein?
3. What is the chief difference between the structure of an artery and the structure of a vein?
4. How does the structure of a capillary compare with that of veins and arteries?
5. How does the function of a capillary compare with that of veins and arteries?
6. At what point in the circulation does the blood appear to flow at the slowest rate?

Further Evidence

1. Study the flow of blood in tadpoles.

2. How does the circulation of blood in the webbed feet of frogs compare with that of the goldfish fins?

New Problems

1. How is the circulation of the blood affected by changes in the temperature?

2. Does the size of an animal affect the rate at which its blood circulates?

Investigation 10

Problem

How is the circulation of the blood in cold-blooded animals affected by changes in temperature? (How does temperature affect the rate of heartbeat?)

Background Information

In this investigation you will study the circulatory systems of two invertebrates, the earthworm and the water flea, Daphnia. Your background research should provide information on the following:

The Earthworm -
- a. structure of heart
- b. blood vessels
- c. path of blood through circulatory system
- d. how oxygen enters and carbon dioxide leaves the blood
- e. comparison of blood with that of human beings

The Daphnia -
- a. structure of heart
- b. blood vessels
- c. why the circulatory system is called an "open" system
- d. how oxygen enters and carbon dioxide leaves the blood

Prediction

Hypothesis

Design for Collection of Data

Design One

Apparatus - paper towel, tray, large earthworm (living), ice cubes, water, thermometer

1. Place a live earthworm on damp paper toweling in a tray. If you look carefully you will see the dorsal blood vessel. When this vessel contracts, it is emptied of blood and seems to disappear. Then it begins to fill up with blood, and you can see it again. Each contraction corresponds to one heart beat.

2. Count the number of times the blood vessel contracts in one minute. Do this five times and average the results. Record in the table under observation.

3. Compare your results with those of other students.

4. Now change the temperature of the environment of your earthworm. Put it in a tray and barely cover it with water. Use ice cubes to cool the water until it is 10 to 20 degrees below the room temperature. Now wait for five minutes or so.

5. Make five one-minute counts of blood vessel contraction. Average the results and enter them in the table.

Design Two

Apparatus - Daphina (living), thermometer, medicine dropper, microscope slide with well, crushed ice, hot water, microscope, small beaker, large beaker

1. Make sure you are completely familiar with the structures of the Daphnia. Don't confuse the beating heart with the rhythmical motion of the legs. The water temperature should be the same as room temperature before starting. (See Thurber, page 125).

2. Using the medicine dropper, place one Daphnia in the well on the slide. Soak up excess water with a piece of paper towel but do not allow the water to evaporate completely.

3. Count the number of heartbeats in 15 seconds and then multiply your answer by four to get the rate per minute. Since the heart beats very rapidly, it may be very difficult to count the beats. Try tapping a pencil on a piece of paper and then count the dots. You should have at least three trials. Record your results below.

4. Place a small beaker of Daphnia into the large beaker containing water and crushed ice. Stir the water in the Daphnia beaker with the thermometer. When the water temperature reaches about 25°(F) below room temperature, quickly transfer a Daphnia to a slide and make at least three counts of the heartbeats.

5. Repeat the above procedure, but instead of using cold water, use hot water which is about 25° above room temperature.

Procedure

Record any changes in procedure below.

Observations

Design One:	Trial Number	Contractions per Minute	
		Room Temp.	20° Below Room Temp.
	1		
	2		
	3		
	4		
	5		
	Average		

Design Two	Trial Number		Contractions/Minute	
		Room Temp.	20° Below Room Temp.	20° Above Room Temp.
	1			
	2			
	3			
	Average			

1. Did all of the earthworms in the first text exhibit the same rate of blood vessel contraction? If not, how might the variations be explained?

2. What was the range of contractions (or heartbeats) in the (a) earthworm (b) Daphnia

3. Why was it necessary to have more than one trial?

4. Which is likely to be more reliable, the average obtained by your group or the average obtained by the entire class? Why?

Graphing Data

Construct a graph to show the results obtained with Daphnia. Which is your independent variable? Your dependent variable?

Interpreting Data

1. What effect did lowering the temperature have on the rate of heartbeat?

2. What effect did raising the temperature have on the rate of heartbeat?

3. If the blood flows more slowly at lower temperatures than at higher temperatures, what can we conclude about the rate of gas exchange between the cells and the blood?

4. When would you expect the earthworm or Daphnia would take in more oxygen, at low temperatures or at high temperatures?

5. What can we conclude about hibernation from this investigation?

Further Evidence

Would you expect similar results with vertebrate animals?

New Problems

1. What effect would stimulants or tranquilizers have on the heartbeat?

2. What other changes in the environment might affect the rate of heartbeat?

Investigation 11

Problem

How is the rate of circulation (heartbeat or pulse) affected by muscular activity?

Background Information

Since this investigation will involve the human heart, you should have some background knowledge on:

1. the structure of the heart
2. the pulmonary arteries
3. the pulmonary veins
4. the path of the blood through the circulatory system

The heart beats about 72 times each minute in the average adult. With each contraction of the left ventricle, about 80 milliliters of blood are forced from the heart into the main artery or aorta. In one minute, more than 5 liters of blood pass through the heart. This amount is nearly equivalent to the total amount of blood in the average adult's body. Thus, all the blood in the body passes through the heart about once every minute.

The rate of heartbeat is controlled partly by chemicals. When the blood contains large amounts of carbon dioxide, the acidity of the blood is high. The heart rate then speeds up until the extra carbon dioxide has been removed by the lungs. Heart rate is also controlled by blood pressure.

The heart's nerve center is called the pacemaker. It is found in the right auricle where blood from the body enters. The pacemaker controls the contraction of the muscles of the heart.

When the heart muscles contract, blood is pushed through the blood vessels. One of these vessels is close to the surface in your wrist. You can feel a surge of blood passing through it each time the heart beats. We call this surge of blood the pulse. The number of pulses corresponds to the number of heart contractions or heart beats.

Prediction

Hypothesis

Design for Collection of Data

1. Measure your pulse rate by placing a finger on the underside of the wrist just below the base of the thumb. For practice, count the number of pulse beats for one minute. Now sit quietly for two or three minutes. Find your pulse rate while resting. Make three measurements and calculate the average. Record results below.
2. Now, stand up, and while standing, measure your pulse rate as before. Record your results again.
3. Next, hop up and down on one foot, as fast as you can, about twenty times. As soon as you have completed this exercise, measure your pulse rate again. Record results.

Procedure

Record any changes in the above design.

Observations

Student	Trial	Pulse Rate Resting	Pulse Rate Standing	Pulse Rate After Exercise
	1			
________	2			
	3			
	1			
________	2			
	3			

Organizing Data

1. What was the highest rate in your group?
2. What was the lowest rate in your group?
3. What was the range (from lowest to highest)?
4. What was the average rate for your group for resting, for standing and after exercise?

Graphing Data

Construct a bar graph to show the results you obtained.

Interpreting Data

1. What effect does muscular activity have on the rate at which the blood circulates? Why?
2. When would the rate of circulation be at its lowest?
3. What do you think was happening between the blood and the muscle tissues in your leg when you were hopping?
4. Why does your pulse rate not return to normal immediately after you stop exercising?

New Problems

1. What effect do factors such as height, age, and weight have on the rate of circulation?
2. Do your emotions affect your heart rate.
3. Is heartbeat affected by altitude above sea level?

Investigation 12

Problem

How are leaves adapted by structure for the manufacture of food?

Background Information

Leaves vary in size, form and structure. Select three of four different kinds of leaves (complete with their twigs) to study their external features in detail. Observe each of the leaves carefully, keeping in mind that one of their primary functions is to expose the chloroplasts in their cells to as much sunlight as possible. Make diagrams to show external parts. Your observations and research should provide information on the following:

1. external structure of leaves
2. arrangements of leaves on twigs or stems
3. types of leaves
4. leaf shapes
5. leaf margins
6. leaf venation

Design for Collection of Data

Apparatus - leaves from coleus, begonia or geranium plants, prepared slide of leaf cross-section, slide and cover glass, microscope or microprojector.

Part One:

1. Study a prepared slide or a cross-section of a leaf or prepare your own cross-section. (See Exploring Life Science, page 382)
2. Focus upon the leaf cross-section with the low power of the microscope. When you have found a portion of the section which is especially clear, change to high power. Compare what you see with a diagram from a reference text such as Exploring Life Science, page 385-399.

Part Two

1. Prepare a slide of the lower epidermis of the geranium, coleus or begonia leaf. Use the tear technique as shown in Exploring Life Science, page 371. The lower epidermis will appear as a thin, transparent skin.
2. Mount a small portion in a drop of water on a slide and add a cover glass. Examine first with low power and then with high power. Compare what you see with diagrams such as those found in Exploring Life Science, page 383-385.

Procedure

Record any changes in the above design.

Observations

1. The upper layer of the leaf will appear as a single row of cells. This is the upper epidermis. Does it have a waxy substance or cuticle on it?
2. What is the general shape of the epidermal cells?
3. The palisade layer (mesophyll), is found just below the upper epidermis and is composed of elongated cells arranged in vertical rows. How many rows can you count?
4. What are the tiny green structures in the palisade cells?
5. How do the spongy cells compare with the palisade cells? Which layer is more compact?
6. Which layer of cells, palisade or spongy, contains more chloroplasts? What does this tell you?
7. What do you think the spaces between the spongy cells are used for?
8. The spongy layer contains numerous veins. If the leaf on your slide was cut across a vein, the vein will appear as a group of small, thin-walled and thick-walled cells. If your leaf was cut along a vein (longitudinally), you will see thick-walled tubes with spirals in the walls. Study your slide and see if you can find both cross and longitudinal view of a vein.
9. What two kinds of tubes are found in a vein?
10. Make a drawing of a cross-section of your leaf in the space below. Label the following parts: cuticle, upper epidermis, palisade cells, spongy cells, vein, lower epidermis, stomata.

11. What is the name given to the tiny openings in the lower epidermis?
12. What surrounds each stoma (stomate)?
13. About how many stomates can you count in the microscopic field?
14. In what way are the guard cells different from the surrounding cells?
15. In the space below, draw a group of lower epidermal cells, including at least one stomate. Label epidermal cell, stomate, guard cell.

Interpreting Data

1. Do all regions of a leaf contain cells with chloroplasts?

2. Why are leaves generally darker green in color on the upper surfaces than on the lower surfaces?

3. Why are the cells of the upper and lower epidermis translucent?

4. Why are most of the openings into a leaf located on the underside (in the lower epidermis)?

5. What two important functions are performed by the veins in the leaves?

New Problems

1. Do the leaves (needles) of cone-bearing trees have the same structures as those found in broad leaves?

2. What special adaptations do the leaves of desert plants have?

3. Can chlorophyll be separated from the leaves of a plant?

Investigation 13

Problem

To remove chlorophyll from a leaf.

Background Information

Chlorophyll is the green pigment found in the cells of green plants. It is a complex substance consisting of a mixture of many substances. The chief substances are carbon, hydrogen, oxygen, nitrogen and magnesium. Not all chlorophylls are exactly the same. Scientists have discovered at least four different kinds. The chlorophyll is a plant cellsis usually contained in tiny structures called chloroplasts. With the aid of the electron microscope, scientists have been able to look inside the chloroplasts and find out how the chlorophyll is arranged. Some of the latest science books in your library may have pictures showing the inside of a chloroplast.

Chlorophyll is not the only pigment found in plant cells. Various red, orange and yellow pigments are also found in plant cells. Usually there is so much green pigment that the other colors do not show up. Some plants do have a variety of colors in their leaves, and, in many plants the leaves turn various colors in the fall.

Design for Collection of Data

Apparatus - deep pan, beaker, bunsen burner, ring stand, graduate, large test tube or glass cylinder, glass rod, alcohol, benzol, fresh spinach or beet plant

1. Set up a water bath over a bunsen flame.
2. Chop up some beet or fresh spinach leaves and put them in a beaker. Have the beaker about half full of leaf fragments.
3. Add alcohol until the leaf parts are covered and then place the beaker in a water bath until the alcohol becomes dark green in color. What is the purpose of the alcohol?
4. Now pour about 50 ml of the colored alcohol into a glass cylinder and add to it 10 ml of water. Wait a few minutes for the mixture to cool.
5. AT THIS POINT, MAKE SURE THAT ALL OPEN FLAMES ARE PUT OUT BECAUSE YOU ARE ABOUT TO USE BENZOL. BENZOL IS ALSO KNOWN AS PETROLEUM ETHER, AND IT IS FLAMMABLE AND EXPLOSIVE!
6. Add 60 ml of benzol to the contents of the glass cylinder and stir the contents for a minute or two with the glass rod. Then let the contents cool and settle.

Procedure

Record any changes in the procedure in the space below.

Observations

1. What happened to the liquid after it cooled and settled?
2. How many layers of pigment were formed?
3. In which layer of pigment was the chlorophyll found?
4. What pigments might you expect to find in the other layers?
5. Make a sketch to show your observations.

Interpreting Data

1. Is chlorophyll found in only those leaves which are green in color?
2. Why are leaves which are non-green in color able to manufacture food?
3. Why do leaves turn non-green colors in the fall?
4. Why is it that the leaves of some plants are much darker green than other plants?

New Problems

1. Blue-green algae do not have chloroplasts. Does this mean that they do not contain chlorophyll?
2. Chlorophyll causes the green color in leaves. What substances cause the yellow, red and orange colors?
3. Is it impossible for a leaf to manufacture food without chlorophyll?

Investigation 14

Problem

To investigate the role of light in the food-making process.

Background Information

There are two phases in the food-making process: a light phase which requires light energy, and a dark phase which can take place without light. Only in the first stages of photosynthesis is light required.

White light is composed of light of different wave lengths. It is a mixture of red, orange, yellow, green, blue, indigo and violet waves --the colors of the rainbow. Chlorophyll absorbs all of these waves except the green waves. The green waves are reflected and for this reason chlorophyll appears green.

In the light phase, chlorophyll receives energy from a light source and changes this energy into chemical energy. The chemical energy is then used to break down water into hydrogen and oxygen. The oxygen is then given off, but the hydrogen is kept for use during the dark phase.

In the dark phase, carbon dioxide and hydrogen are used in a series of chemical changes that eventually result in the production of simple sugar (glucose). From this glucose green plants can make all the other foods they require to live and grow.

Design for Collection of Data

Apparatus - geranium plant, black cardboard paper, paper clip, water, alcohol lamp, pan for water bath, ring stand, Lugol's solution or iodine solution, medicine dropper, Petri dish (2)

1. Place the geranium plant in a dark cupboard for 24 hours. During this time the starch in the leaves will be removed. Where will the plant take it?
2. Take the plant out of the cupboard and immediately cover one of its leaves (A) with the black cardboard. The paper clip may be used to hold the cardboard around the leaf.
3. Place the plant in bright sunlight for one or two days. Make sure that the leaf covered with the black cardboard does not receive any light.
4. Select a leaf that has been exposed to the sunlight and remove it from the plant. Call it leaf B.
5. Test leaf B for starch using the following procedure: to test any leaf for starch, you must first remove its pigments. If the leaf is first heated in water, the cell walls will break up, and it will be easier to remove the chlorophyll. Then the leaf should be heated in alcohol. The safe way to do this is to use a water bath. You heat the water in the pan, and the water heats the alcohol in the beaker. When you put a green leaf in the beaker, the alcohol soon absorbs the green pigments (as well as the other pigments), and the leaf becomes white. If the leaf does not turn white, more alcohol is needed, since a given amount of alcohol will absorb only so much chlorophyll. After the leaf is white, use the medicine dropper to put some Lugol's or iodine solution on it. Wait two or three minutes to see if a blue-black color appears. This color indicates the presence of starch.

6. In which leaf did the largest amount of starch appear to be present? How do you know?

Interpreting Data

1. Why is light needed in the process of photosynthesis?

2. Does any part of photosynthesis occur in the absence of light? Explain.

Further Evidence

1. Would you have obtained the same results if only part of leaf B had been exposed to the sunlight?

2. Why is there little plant life in the deeper parts of lakes and oceans?

New Problems

1. Would you have obtained the same results if leaf B had been exposed to strong artificial light instead of sunlight?

2. Sugar is found in the bulbs of sprouting onions when they are exposed to light. Would this indicate the importance of light in the photosynthesis process?

3. Do the leaves of plants produce more food in bright sunlight than in weak sunlight?

4. Is sunlight needed to produce chlorophyll?

5. What effect would a flashing light have upon the rate of photosynthesis?

6. Does the color of the light affect the production of food? (Would a leaf produce more food in green light than in red light?)

Investigation 15

Problem

Do plant cells need chlorophyll in order to manufacture food?

Background Information

In most green plants chlorophyll is contained in tiny structures inside of the cells called chloroplasts. In the higher developed plants most of the cells containing chloroplasts are found in the leaves. In some of these plants, chloroplasts are located in only certain parts of the leaves. Such leaves are known are variegated leaves. They are found on such plants as the silver-leaf geranium and the coleus plant. The parts which are non-green do not contain chloroplasts and therefore do not contain the pigment chlorophyll.

In preparation for this investigation make a detailed diagram of a typical green plant cell showing the main structures. Exploring Life Science, page 373 and 400 may be used. In addition, review the main parts of a leaf cross-section covered in a previous investigation. Note particularly the location of the chloroplast-containing cells.

Design for Collection of Data

Apparatus - coleus or silver-leaf geranium plant, alcohol, Petri dishes (2), forceps, Lugol's solution or iodine solution, 2 beakers (250 ml.)

1. Draw an outline of a leaf of the plant in the space provided for in the section on Observations.
2. Fill a beaker about half full of water and heat it to boiling. Immerse a leaf from the plant in the boiling water for a few minutes. This will soften the leaf and make it easier to remove the chlorophyll. (The best results will be obtained by using a leaf from a plant which has been exposed to bright sunlight for several hours.)
3. Using forceps, remove the softened leaf from the water and place it in a beaker half full of warm alcohol. Leave the leaf in the alcohol until all of the green color has disappeared from the leaf. (To speed up the reaction your teacher might suggest that you place the beaker with the alcohol and leaf in a water bath.)
4. When all of the green pigment has been removed from the leaf, take the leaf out of the alcohol and rinse it under the cold water tap. Then spread the leaf on a Petri dish. Cover the surface of the leaf with dilute Lugol's solution or iodine solution. Why is this done?
5. After five minutes or so, rinse off the solution under the cold water tap. Spread the leaf in the bottom of a clean Petri dish. Sketch an outline of the leaf and show the colors of the different areas.

Procedure

If you made any changes in the design, record them below.

Observations

1. Use the space below for sketches of the leaf at the start of the investigation and at the completion.

2. Compare the two diagrams you made. What color did you find in the non-green part after the investigation? What color did you find in the green part after the investigation?

3. How did the area showing the presence of starch compare with the area containing chlorophyll?

Interpreting Data

1. Why did only part of the leaf turn black after being flooded with Lugol's solution or iodine solution?

2. Was food manufactured in all of the cells in the area of the leaf which turned black? If not, in which cells was food not made?

3. Would a green plant die if all the chlorophyll in it were removed? Explain your answer.

New Problems

1. In some plants, such as the Iresine, all parts of the plant are non-green colors. How do these plants obtain the food they require?

2. Why does chlorophyll appear green in color?

Investigation 16

Problem
To investigate the exchange of gases which occurs during photosynthesis.

Background Information

1. What gases are found in the atmosphere?

2. What conditions must exist in an aquarium in order for it to be balanced?

Design for Collection of Data
Design One
Apparatus - 6 test tubes (label them A, B, C, D, E, F), rubber stoppers (6), sprigs of Elodea (6), aquarium water, bromothymol blue, test tube holders, soda straw

1. Fill each test tube with aquarium water. Add a few drops of bromothymol blue to each test tube. With the soda straw, blow into each test tube of water until the solution turns yellow. What causes the solution to turn from blue to yellow?

2. Place sprigs of Elodea (with buds on their tips, if possible) into test tubes A, B, C and D. Do NOT put any Elodea sprigs into test tubes E and F. Stopper each test tube.

3. Place test tubes A, B, E and F into bright sunlight. Place test tubes C and D in a dark cupboard. Record your observations below.

4. What is the purpose of C and D? E and F?

Design Two
Apparatus - 2 bell jars (labelled A and B), 2 geranium plants, dry lye, dilute hydrochloric acid, marble or limestone chips, materials for starch test

1. Place the two geranium plants in darkness for 24 hours. What effect will this have upon the starch in the leaves?

2. Cover each plant with a bell jar. Under jar A, place a small dish of dry lye. This will absorb most of the carbon dioxide from the air under the jar.

3. Under jar B, place an open bottle of hydrochloric acid mixed with the marble or limestone chips. What is the purpose of the acid and chips?

4. Place the two sets of apparatus in bright sunlight for several hours. Then remove a leaf from each plant and test it for the presence of starch. Record your observations below.

Design Three

Apparatus - 2 beakers (labelled A and B), 2 test tubes, 2 glass funnels, 10 - 12 sprigs of Elodea, wood splint, baking soda

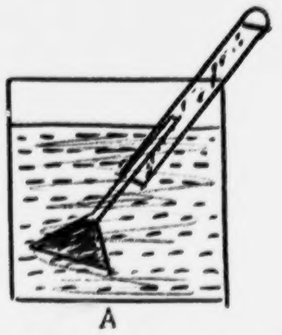
1. Heat a jar of water to the boiling point. Then let it cool. What effect will this have on the gases dissolved in the water?

2. Add a quarter teaspoonful of baking soda to the water and stir until dissolved. What gas will be produced by the solution of baking soda and water?

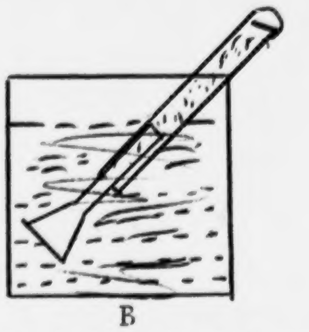
3. Fill each beaker with this water. In beaker A, place 5 - 6 sprigs of Elodea and cover them with an inverted funnel. Place a test tube filled with water over the end of the funnel. Make sure the open end of the test tube is below the level of the water in the beaker.

4. Set up beaker B in exactly the same way, but do not use any sprigs of Elodea under the funnel. What is the purpose of beaker B?

5. Place both apparatus A and apparatus B in bright sunlight or close to a very bright light. Let stand for several hours or until the level of the water in the test tube falls to the level of the water in the beakers.



A



B

6. Remove the test tube from beaker A and immediately test the gas in the test tube with a glowing splint. Do the same with the test tube from beaker B.

Procedure

If you made any changes in the above designs, indicate them below.

Observations

Design One 1. What happened to the water in test tubes A and B?

2. Were the results the same for test tubes C and D?

3. Why did the water in test tubes E and F remain yellow?

Design Two 1. Make a sketch to show the colors in the two leaves after they were tested for starch.

2. How did the amount of starch in the two leaves compare?

3. Why would there be some starch in the leaf from under jar A?

4. Why did the leaf from jar B contain a greater amount of starch?

Design Three

1. Did the glowing splint burst into flame in both test tubes?

2. If the glowing splint did not burst into flame, did it glow more brightly in one test tube than another? Which one?

3. If the glowing splint had gone out when it was placed in the test tubes what would this have indicated?

4. As the gas collected in the test tube, what happened to the level of the water in the test tube?

Interpreting Data

1. What gas is taken in by plants during photosynthesis?

2. How do we know that this gas is not taken in during hours of darkness?

3. How does photosynthesis compare with respiration?

4. Do green plants give off all the oxygen they produce during photosynthesis?

5. How does photosynthesis compare with respiration?

6. What might cause the death of some of the animal life in a balanced aquarium?

Further Evidence

1. Would you get similar results if you used germinating seeds instead of geranium plants?

2. How would the brightness of the light affect the rate at which carbon dioxide would be taken in?

3. How is the earth's animal life affected by large-scale clearing of forested areas?

New Problems

1. The water in small ponds which have great numbers of algae plants is often short of oxygen during certain periods of the 24 hour day. While at other times there is an excess of oxygen. Why do you think it varies? When would you expect to find the greatest amount of carbon dioxide? What effect would this variation in oxygen and carbon dioxide content have on the animal life in ponds?

2. How do gases enter and leave the leaves of green plants?

Investigation 17

Problem

What role do the stomates of the leaves play in the food-making process?

Background Information

As you learned in the previous investigation, the leaves of plants take in carbon dioxide and give off oxygen during photosynthesis. The diffusion of gases into and out of the leaf takes place through the tiny openings or stomates. In this investigation you will study the method by which the stomates control the entry and exit of gases and how they affect the food-making process in the leaf. In preparation for this investigation, review the material covered in investigation 12 and also answer the following questions:

1. On which surfaces of the leaf are most stomates found?

2. How many stomates are found on an average leaf?

3. What function is performed by the guard cells which surround the stomates? Why are they able to manufacture sugar?

4. Make a sketch to show the stomate and its surrounding cells.

Design for Collection of Data

Part A

Apparatus - microscope, fresh leaves, razor blade, 5% glucose solution, medicine dropper, forceps, slide and cover slip, paper towel

1. Prepare a tear section of a fresh leaf (see Exploring Life Science, page 371). Make sure you use the lower surface.
2. Cut off a small piece of the tear section and immediately place it in a drop of water on a slide. DO NOT ALLOW IT TO DRY. Cover with a cover slip.
3. Study this piece under the microscope, using low power and then high power. Record your observations in diagram form below.
4. Prepare another tear section and place it on a slide with a cover slip. Put three drops of the glucose solution on one side of the cover slip (see Exploring Life Science, page 375, bottom). Use a piece of the paper towel to draw the solution into the tissue.
5. Study this tear section under the microscope. Record your observations below.

Part B

Apparatus - 2 geranium plants, petroleum jelly, carbon tetrachloride, materials for starch test

1. Place the two plants in darkness for 24 hours.
2. On the following day bring them out into the light and on one of the leaves of the first plant (A) smear pertrleium jelly over the entire surface of the leaf.
3. Now place both plants (A) and (B) in bright sunlight for the next day.
4. From plant (A) remove the leaf that was smeared with the petroleum jelly. Rub off the petroleum jelly with carbon tetrachloride. Now test this leaf for the presence of starch.

5. Remove a leaf from plant (B) and also test for starch.

Procedure

Record any changes in your procedure in the space below.

Observations

Part A

1. Make a sketch to show: a) the stomate and guard cells without glucose; b) the stomate and guard cells with glucose.
2. What was the main difference between the guard cell shapes? How did this affect the size of the stomate?
3. What conditions must exist around the guard cells in order for them to cause the stomate to open?
4. What structures are found in the guard cells that are not found in the other cells in the lower epidermis?

Part B

1. Did both leaves contain the same amount of starch? If not which leaf contained more starch?
2. What effect did the petroleum jelly have on the food-making function of the leaf? Why?

Interpreting Data

1. The guard cells contain chloroplasts. In sunlight sugar is manufactured in these bodies. When this happens, the sugar concentration of the guard cells increases. How does this affect the flow of water molecules through the membrane of the guard cells?
2. What shape do the guard cells have when they are swollen with water?
3. When would the stomates become smaller?
4. How do the stomates control the manufacture of sugar in the leaves?

New Problems

1. Is there any relationship between the number of stomates on a leaf and the habitat in which the leaf is found?
2. Why would a cactus plant have fewer stomates than a plant that does not live on the desert?
3. Is oxygen the only substance given off through the stomates during photosynthesis?

Investigation 18

Problem

How do leaves obtain water as a raw material they need for photosynthesis?

Background Information

Plants require carbon dioxide and water in order to manufacture sugar in the chloroplasts of their leaves. These raw materials must be obtained from the environment of the plant. In a previous investigation you learned that carbon dioxide is taken into the leaves of plants from the air around them. In this investigation you will study how plants take in water through their roots and how they transport this water to the leaves. Your background research should give you an understanding of the structure of roots and stems to enable you to better understand how they are adapted for the function of providing water for the leaves.

Part A The Structure of the Root

Examine specimens, slides and diagrams of roots. Gather information on the following:

1. types of roots
2. external structures of roots
3. internal structures of roots

Your information should include labelled diagrams.

Part B The Structure of the Stem

Examine specimens, slides and diagrams of stems. Gather information on the following:

1. types of stems
2. external structures of stems
3. internal structures of stems

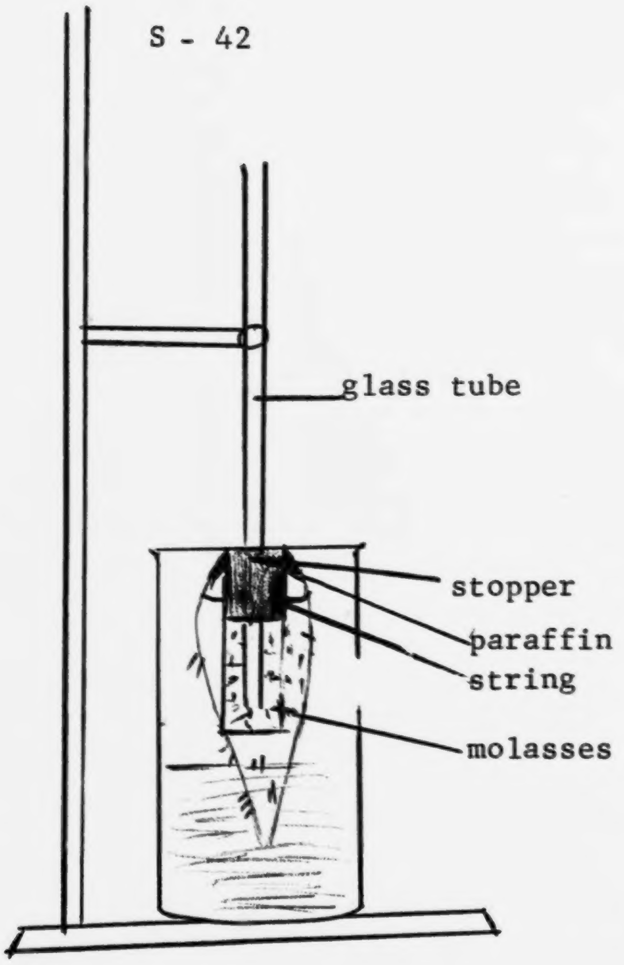
Include labelled diagrams

Design for Collection of Data

Part A

Apparatus - large carrot, molasses, beaker, 1-hole stopper, hollow glass tubing 2' long, paraffin, yardstick, support stand and clamp, large beaker, cork borer

1. Cut off the tip of the carrot about an inch from the end. Use the cork borer to cut out a "well" in the top of the carrot.
2. Insert the glass tube through the stopper.
3. Fill the "well" in the carrot about half full of molasses. Then insert the stopper and tube in the top of the carrot. Make sure the end of the tube reaches down into the molasses.
4. Use string to tie the carrot tightly to the stopper. Seal around the top of the stopper with melted paraffin. Why must this part be waterproof?
5. Suspend the carrot from a clamp attached to the ring stand. Place the large beaker below the carrot and slowly lower the carrot into the beaker. Add water to the beaker so that about an inch of the carrot is covered with water.
6. Let the apparatus stand overnight.
7. See the diagram on the next page.



Part B

Apparatus - 1 celery stalk with yellow leaves, red food coloring, freshly cut poplar twig, freshly cut corn stem, beaker, knife, hand lens, microscope

1. Stand the celery stalk, the corn stem and the poplar twig in the beaker. Fill the beaker half full of water and add the food coloring to the water. Let the apparatus stand for several hours.

2. Examine the cut ends of the three stems. Use the hand lens.

3. Cut each stem in half. Prepare a thin cross-section of each stem and study it with the microscope. Make sketches to show what you observe.

4. Cut each half of the stem longitudinally. Examine with the hand lens. Make sketches of what you see.

Part C

Apparatus - capillary apparatus, food coloring, water, beaker

1. Fill the capillary apparatus with colored water. Let stand.
2. Compare the water level in each capillary tube.
3. Make a diagram showing the thicknesses of the tubes and the level of the water inside each tube.

Procedure

If you make any changes in the above designs, indicate them below.

Observations
Part A

1. What happened in the glass tube? In the beaker?

2. How do you know that water entered the carrot?

3. How did the water get from the beaker into the molasses inside the carrot?

4. Which solution, the water or the molasses had the greater concentration (was thicker) of dissolved materials in it?

5. Did the level of the molasses in the glass tube stay the same or did it continue to rise?

Part B

1. Make diagrams of the cross-sections of the three stems and indicate the regions of the stems which were colored red?

2. Make diagrams of the longitudinal sections of the three stems and indicate the regions colored red.

3. What change did you observe in the leaves of the celery stalk?

Part C

1. Make a diagram to indicate the level of the water in the various tubes in the capillary apparatus.

2. In which tube did the water appear to rise the highest? In which tube was it the lowest?

3. In which tube did the water appear to rise the fastest? The slowest?

Interpreting Data

1. What is the primary function of the roots as far as the food-making process in the leaves is concerned?

2. What are the one-celled structures which grow out from the epidermis of roots?

3. Root hairs have membranes surrounding them. What happens when there is a higher concentration of water on the outside of the membrane than on the inside?

4. The cell sap inside of the root hairs would correspond to what solution in the carrot experiment?

5. What is the name given to the tubes through which water travels from the roots to the leaves? What are these tubes called in the leaves?

6. Where are the conducting tubes found in dicot plants such as the poplar twig?

7. Where are the conducting tubes found in monocot plants such as corn?

8. What actually is the "string" of a celery stalk?

9. In which type of tube will a liquid rise: (a) the highest? (b) the fastest?

Operational Definitions

Define (a) osmosis (b) capillarity

Further Evidence

1. Why do raisins swell up when soaked in water overnight?

2. How does water move from the root hairs to the central cylinder?

New Problems

What does a plant do with the water that is not used up by the leaves during photosynthesis?

UNIT V

EMBRYOLOGY

THE DEVELOPMENT OF THE CHICK

EMBRYOLOGY: THE DEVELOPMENT OF THE CHICKEN

This unit is introduced to give the student an insight into reproduction and development by sexual as opposed to asexual means.

The student will learn: -

(a) to use the Processes of Science.
(b) to develop some of the basic scientific skills of
    (i) weighing
    (ii) measuring
    (iii) graphing
    (iv) preserving of specimens.
(c) to appreciate fully the life processes of reproduction, growth and development.
(d) to foster a respect for life and living things.

To accomplish the objectives above, this unit is divided into five investigations. Some investigations may contain more than one design.

The main problem that students are asked to keep in mind is "To study how living things begin."

Some guidelines for each investigation are included in the following section.

Some suggestions to be considered BEFORE starting this unit.

This unit will require a great deal of work on your part as a teacher. Some points to consider before you begin the unit are:

1. Where to get eggs: The University Farm will supply eggs to teachers, but they require one weeks notice. The cost is 75 cents per dozen (subject to change). This is much less than the commercial hatcheries.

2. The incubator must be set up AT LEAST ONE WEEK IN ADVANCE of the date you wish to start the study of the FERTILIZED EGG.

3. Once you have placed your eggs in the incubator, let them heat up a few hours before starting your count. In this way the egg will be heated to the correct temperature for germination to take place. Some people start their count at the time they place the eggs in the incubator and find that the embryos are not developing as they should. (i.e. they are a few hours behind). The reason is that germination has not taken place but the count was started.

4. Eggs must be turned AT LEAST TWICE A DAY, EVEN ON WEEKENDS. Failure to do so will result in the embryo sticking to the shell and dying.

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1. Adapted from units developed by Don Hollands, Wayne Phare and Reg Roberts.

5. Water must be present at all times in the incubator for moisture in the air.

6. Some thought should be given to what you will do with the chicks after they hatch. It is wise to keep them for about 7 - 10 days so that the students may observe their growth. Arrangements should be made with a farmer to take them. THEY SHOULD NOT BE GIVEN TO THE STUDENTS TO TAKE HOME. Students do not have the facilities for proper care, which usually results in death to the chicks.

7. The best type of grouping for embryology is two students per group. In this way each student can experience all aspects of embryology.

INVESTIGATION 1

This investigation is set up so that the student may become familiar with the skills of weighing and measuring in the metric system. These skills will be used to study the growth and development of the embryo as it progresses toward a full hatch.

DESIGN A WEIGHING SKILLS

Two scales used for this investigation: The OHAUS HARVARD TRIP BALANCE and The EQUAL ARM BALANCE. It should be mentioned that while the instructions given here are specific to the two scales above, the basic ideas may be applied to any scale. For a reference on the Equal Arm Balance, the teacher may refer to "Introductory Physical Science" (I.P.S.).

DESIGN B MEASURING SKILLS

These exercises are designed to give those students who are new to the metric system some background in it. It may also provide those who are familiar with some practice. Those teachers wishing a reference, may refer to the "Basic Physical Science."

INVESTIGATION 2

SUB-PROBLEM. To locate and identify the parts of a hard boiled egg.

It should be mentioned, that while the student is asked to identify and locate the parts of the hard boiled egg, there is another reason for introducing the hard boiled egg at this time. By having them work with the hard boiled egg, they will get some practice in opening eggs without the danger of damaging an embryo in the process. The hard boiled egg will be followed with the fresh egg (Investigation 3) and then the fertilized egg (Investigation 4).

BACKGROUND INFORMATION

References: Nuffield, Text I. Introducing Living Things.

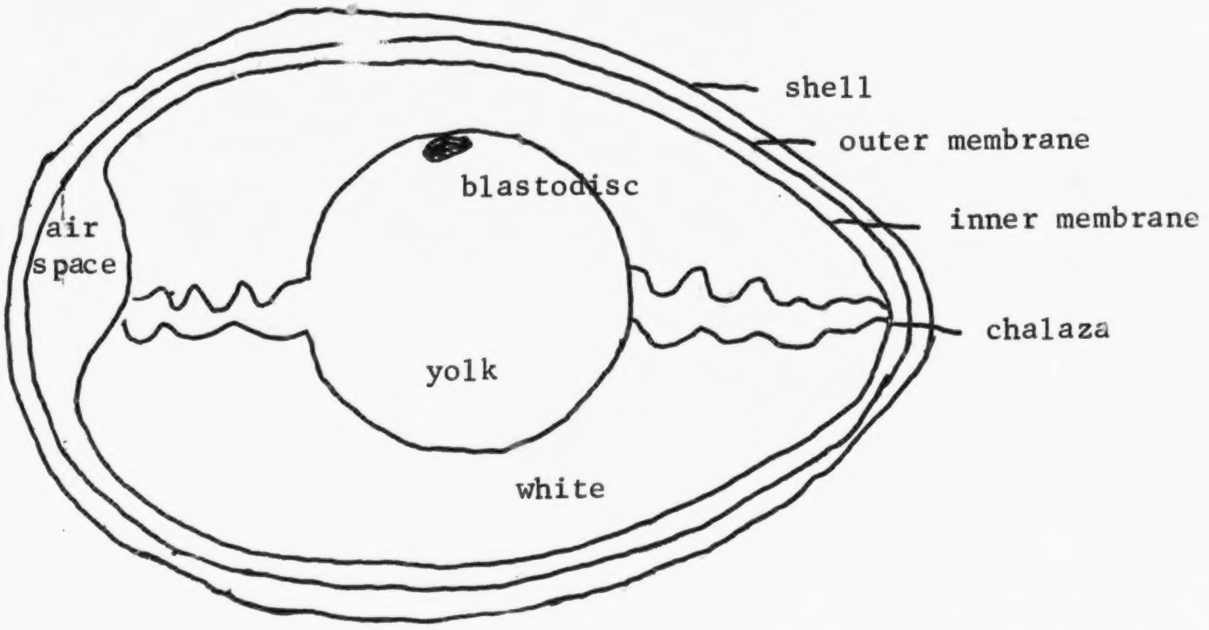
It is important that the students read the background information very carefully so that they will be able to locate and identify each part of the egg.

DESIGN FOR COLLECTION OF DATA

The student is expected to supply his own hard boiled egg for this investigation. These should be placed in the incubator a few hours ahead of class. In this way the students will be working with a warm egg (very similar to the fertilized egg).

Unless care is taken in removing the shell, the student will remove the membranes with it, destroying the air space.

OBSERVATIONS



INTERPRETATION OF DATA

1. There are really three main layers of albumen or egg white: an outer layer, a thick layer and an inner layer. However, when the students are working with the hard boiled egg, these layers do not distinguish themselves very well. They show up better in the fresh egg.

INVESTIGATION 3

SUB PROBLEM: To locate and identify the parts of a fresh egg.

The procedure in this investigation is much the same as for 2, however this time a fresh egg is used. (Refer to comments made under investigation 2).

BACKGROUND INFORMATION

Text I: Introducing Living Things - Pages 80-81.

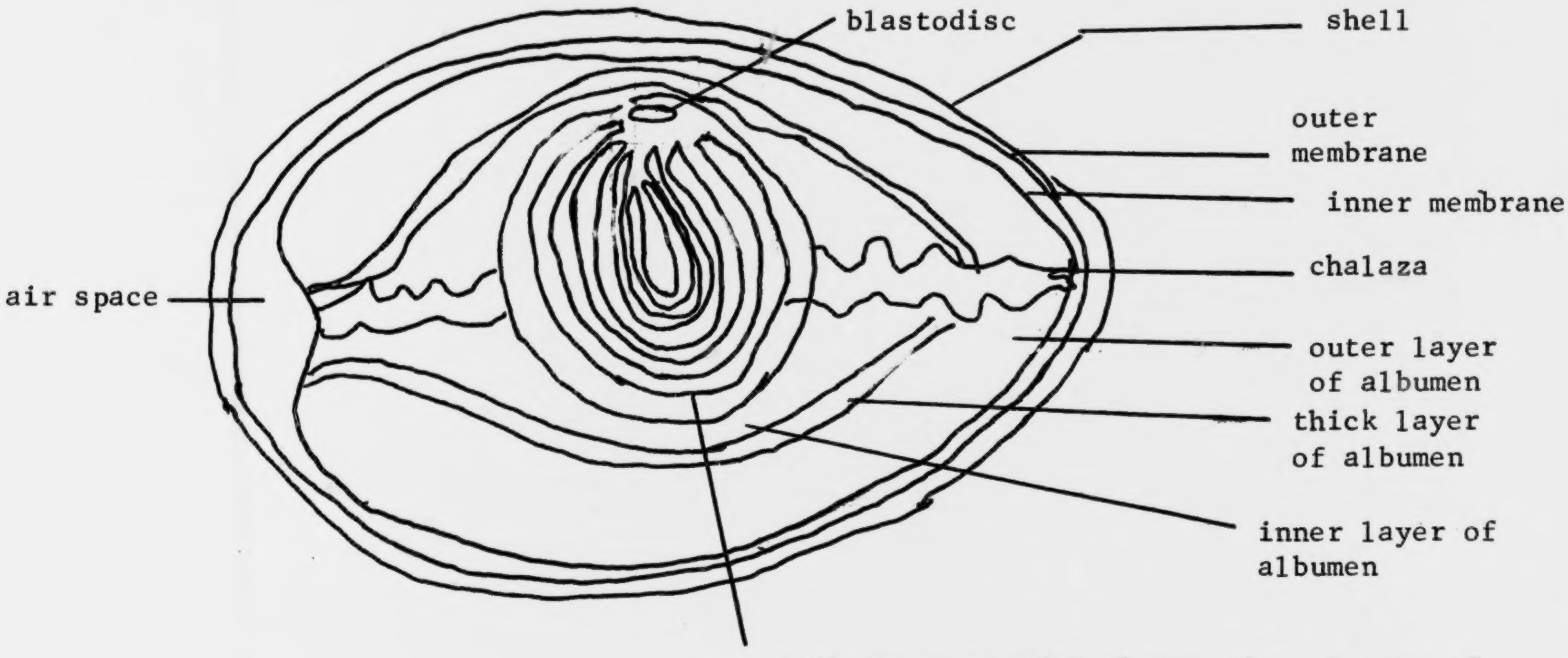
DESIGN FOR COLLECTION OF DATA

Refer to comments for investigation 2. As students are working on this design care should be taken to see that they make an oval, big enough that will enable them to see the entire contents of the egg. They usually make a tiny opening.

While it is suggested that the albumen be flushed down the sink, it may be wise to keep this in a container for disposal later.

OBSERVATIONS:

For a more detailed look at the parts of the egg, you are referred to Biology: Text I: Introducing Living Things, page 81 and Exploring Life Science, page 262.



yolk (upon careful observation, layers of white and yellow may be seen, but this is difficult)

INTERPRETATION OF DATA

6. (a) (from the design) The membrane is not closely attached to the shell at the blunt end.

   (b) Air occupies the space between the inner and outer membrane.

To find the function of each of the structures, the students could refer to Exploring Life Science or Biology Text I. Introducing Living Things. In addition there are two excellent articles from Science World, December 18, 1969, entitled Exploring Inside an Egg and Eggshell.

INVESTIGATION 4

SUB PROBLEM: To locate and identify the parts of a fertile egg.

This is the first time the student will be working with a fertilized egg. It should be impressed upon students that they are now "working with life" and that the utmost care and caution must be taken so that no accidents will occur.

A period or two discussing the moral aspects of embryology is very necessary at this point. Such questions as: "Do we have the right to open these eggs?", "Why are we opening these eggs?" may be asked.

BACKGROUND INFORMATION

1. Again the most useful references of any abundance will be Nuffield Text I and Exploring Life Science. However, the article Exploring Inside an Egg will be most useful here.

   Students should be made aware that fertilization has taken place by sexual rather than asexual means.

2. Refer to Exploring Life Science, page 263 and the article Exploring Inside An Egg for references on the female reproductive tract and refer to accompanying diagram.

3. The instructions in the student's notes are adapted from Nuffield Text I.

4. Students should be introduced to the process of incubation. This is included in the student's notes for this unit.

   The incubator should be set up at least one week in advance of when the eggs are placed in it.

OBSERVATIONS:

The students will be observing a 24-48 hour embryo. For this reason some students will have a difficult time actually locating the embryo. A valuable reference for the student will be Exploring Life Science, pages 259 to 261.

Have them draw a diagram of the yolk, yolk sac and embryo to show relative sizes.

INTERPRETATION OF DATA

1. Students will notice the germ spot has increased in size. Depending on the age of the egg, they may see the starting of blood vessels. Some students may even be able to see the embryo.

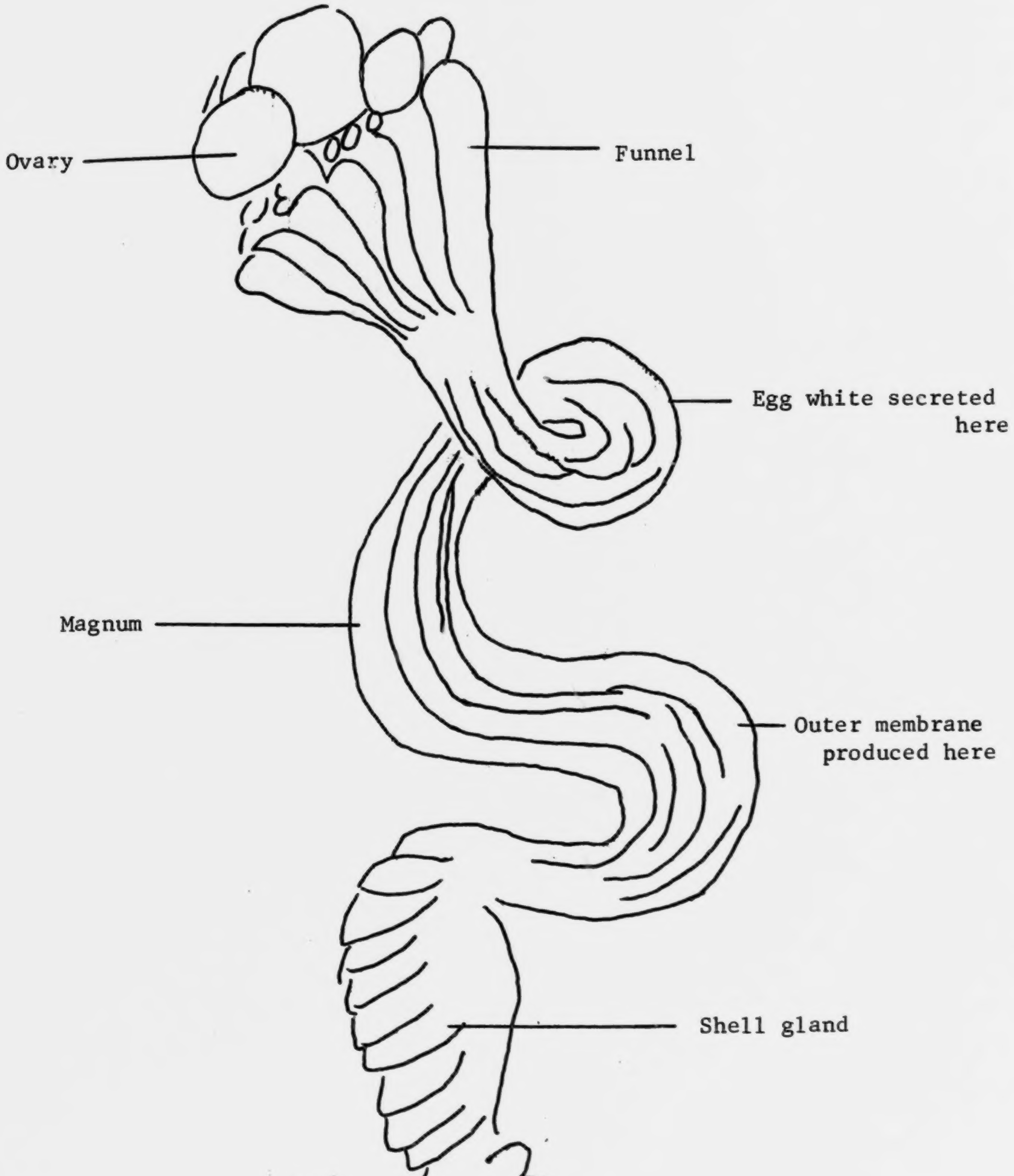
2. Fertilization.

3. No.

4. Eggs should not be handled roughly otherwise damage may result to the embryo.

T-6

DIAGRAM OF ♀ (FEMALE) REPRODUCTIVE TRACT


Ovary
Funnel
Egg white secreted here
Magnum
Outer membrane produced here
Shell gland
Vagina
Cloacal opening

INVESTIGATION 5

SUB PROBLEM: To study the development of the chick embryo.

This investigation is divided into five (5) designs. The embryos studied will be the 3½, 5, 7 and 10 day old. It should be pointed out that while these days will give the student the best understanding of development in the chick, it may be difficult to hit these days dead on, due to holidays, date at which eggs were started, etc. Some people may wish to extend their study of the chicken embryo beyond the 10 day, i.e. 13-day, 15-day, etc. This will be left up to the teacher.

DESIGN FOR COLLECTION OF DATA

A word of caution at this point. It has been noted that students, once they start working on the 3½ day embryo and the following embryos, become so engrossed with the embryo, that they sometimes forget to record their observations on the living specimen. You will have to continually remind them to record their observations.

The designs are basically the same for all the embryos. The following points should be kept in mind however:

1. Have the students open the egg, record their observations and preserve the embryo in one period.

2. Have them carry out the weighing and measuring of the embryo in the second period.

3. Impress upon them the importance of recording everything they see. They should record the new structures they see and record any changes noted in those structures observed earlier.

4. Saline solution is used as a stimulator to keep the heart beating while observations are being made on the living embryo. This however is not very effective after the 5 day embryo.

5. Once all the observations have been recorded, the embryo may then be removed and placed in an alcohol solution. Two methods of preservation may be used:

   A. The embryo may be placed in a 35% solution for ½ hour, then placed in a 50% solution for another ½ hour and finally preserved in a 70% solution of alcohol.

   OR

   B. The embryo may be placed in a 70% solution of alcohol for 24 hours followed by preservation in a 90% solution.

   In these ways the embryo may be preserved, with the least amount of shrinkage to the specimen.

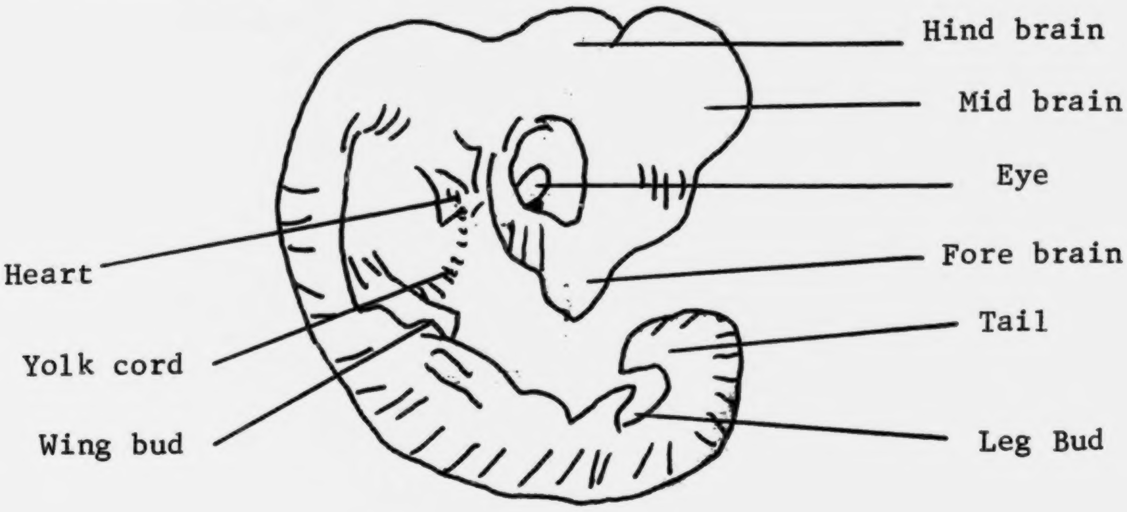
OBSERVATIONS. The students should be encouraged to record all their observations.

The charts provided prove quite satisfactory for this. However they should be encouraged to record any other observations they make as well.

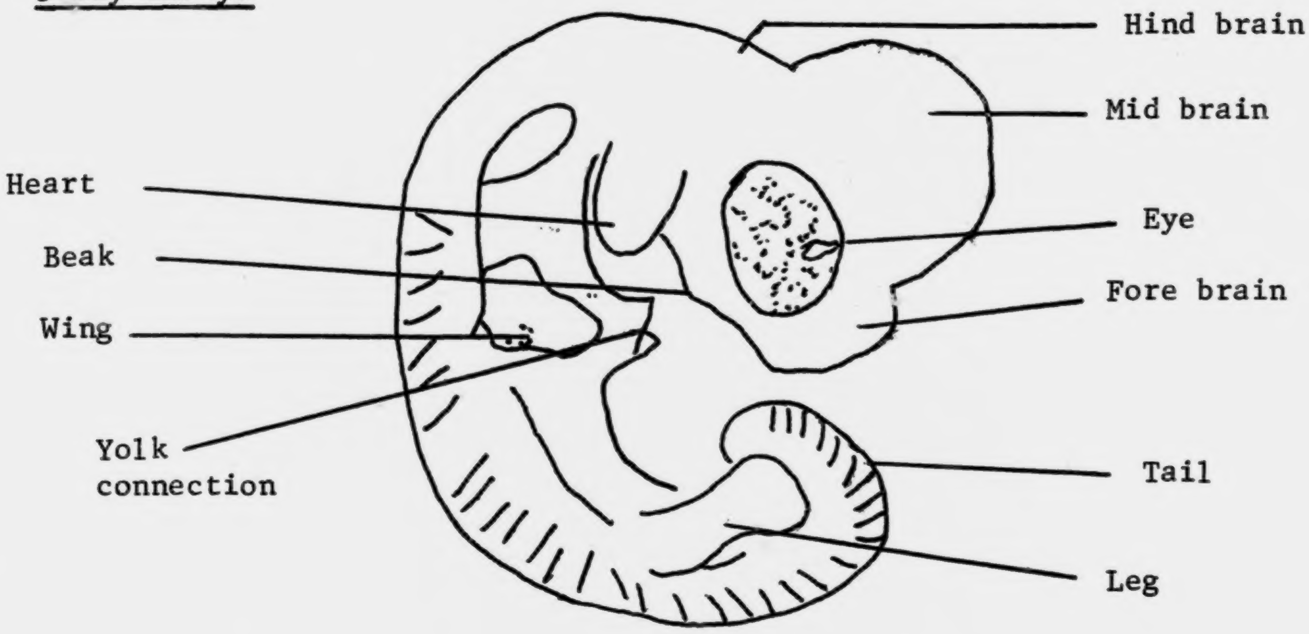
Because the embryos the students work on may not fall right on schedule (e.g. 3½, 5, 7, etc.) you should ask them to match the embryos they are using with the diagram that most resembles it, and then label the diagram. Students should be encouraged to label all the parts they see.

While diagrams are supplied students should be encouraged to draw their own.

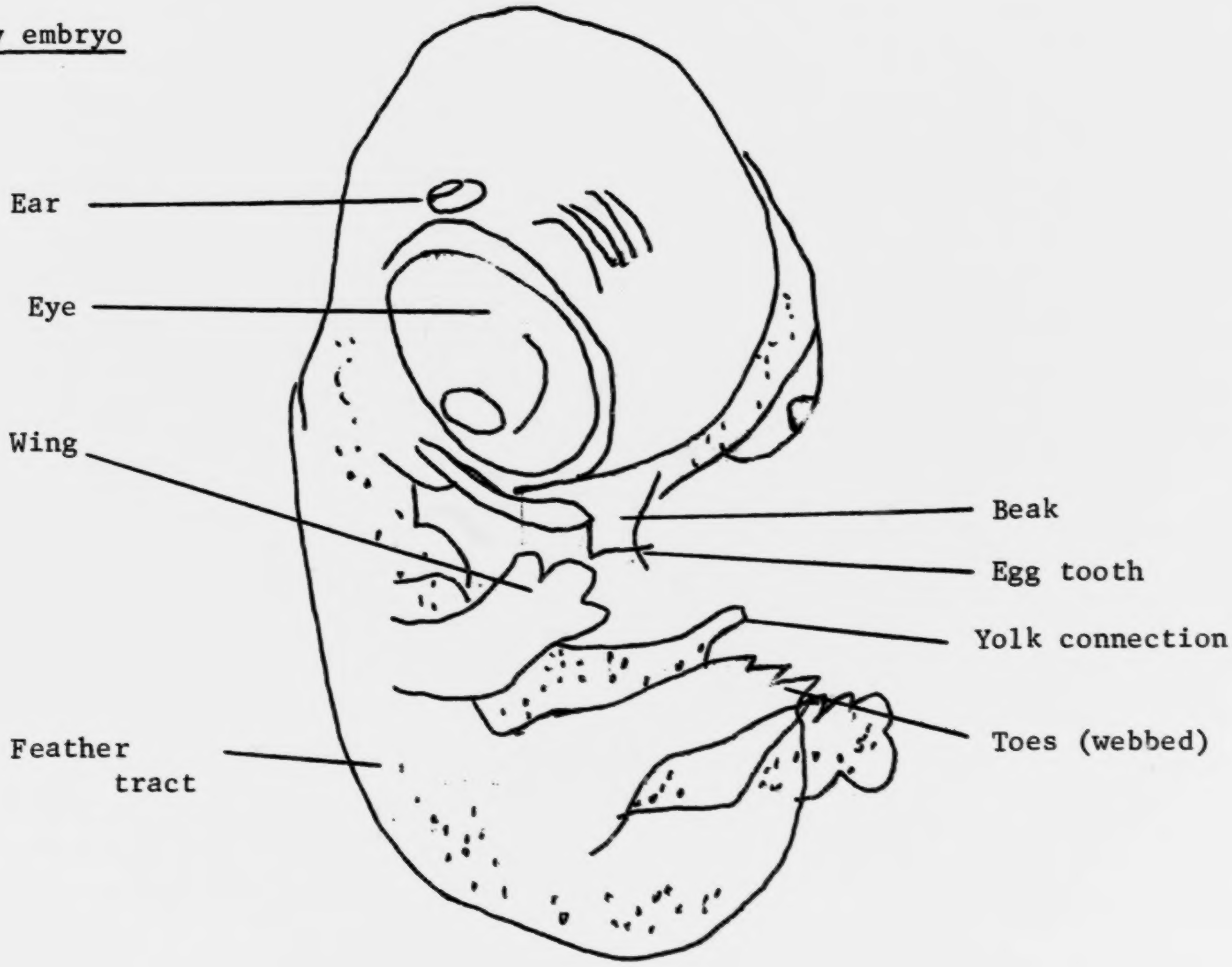
3½ day embryo


Hind brain
Mid brain
Eye
Fore brain
Tail
Leg Bud
Heart
Yolk cord
Wing bud

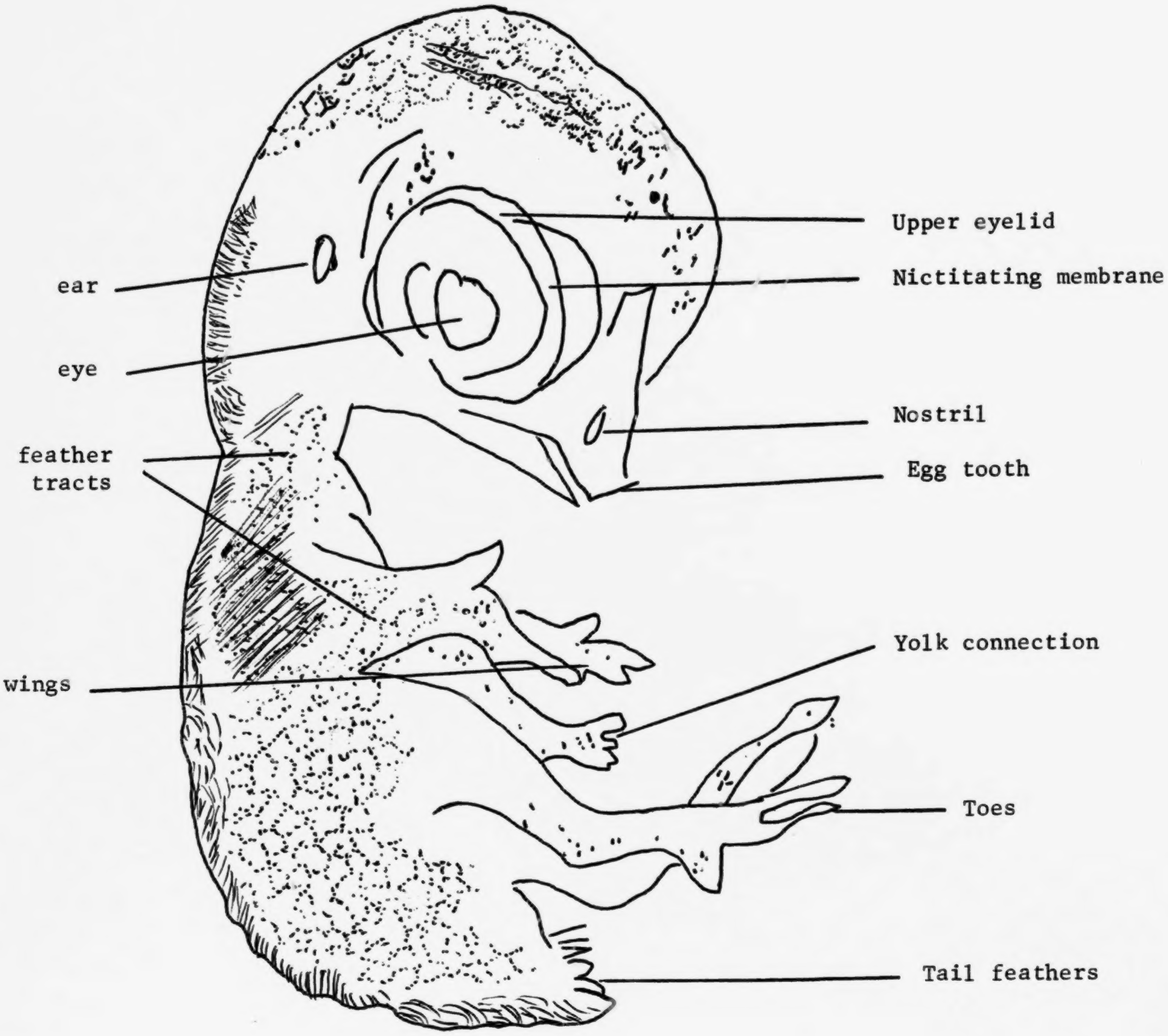
5 day embryo


Hind brain
Mid brain
Heart
Eye
Beak
Fore brain
Wing
Yolk connection
Tail
Leg

7 day embryo


Ear
Eye
Wing
Beak
Egg tooth
Yolk connection
Toes (webbed)
Feather tract

10 day embryo


Upper eyelid
ear
Nictitating membrane
eye
Nostril
feather
tracts
Egg tooth
Yolk connection
wings
Toes
Tail feathers

ORGANIZATION OF DATA

Have the students keep their own record of weights and measurements.

This data may then be placed on the board or on overhead projection transparency for comparison with the rest of the class (refer to comparison chart in student's notes).

Averages may then be taken for each variable you studied.

The data for the number of heart beats per minute may not be very satisfactory for comparison, as it is hard to find a heart beat after 5 days. For this reason the data may be deleted for comparison purposes.

GRAPHICAL REPRESENTATION OF DATA

Have the students draw graphs illustrating the development that took place for: the length, weight, diameter of eye and distance from tip of beak to outside of eye. They should place each factor studied on a separate graph. After they have made a graph using their own data, they could then super-impose a graph of the data obtained for the average of each factor studied.

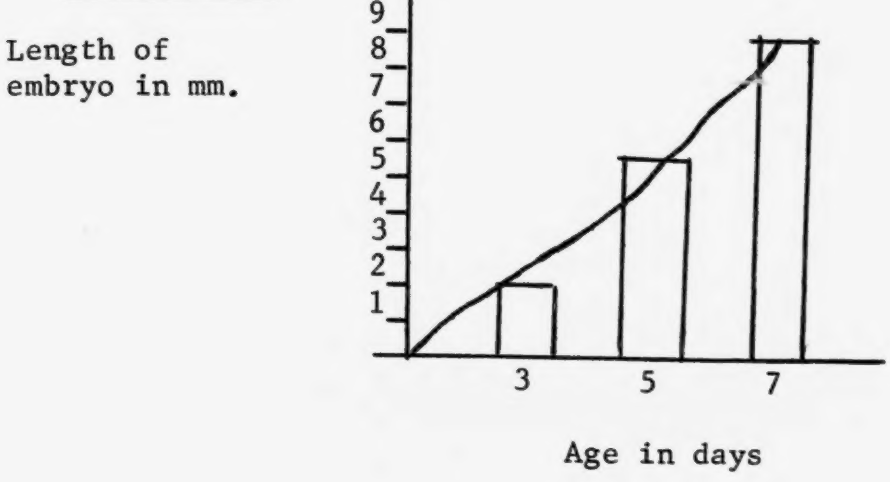
Some teachers may wish to use bar graphs rather than line graphs. This decision is left to the teacher.

This is an excellent opportunity to introduce or review graphing techniques. Some stress should be given to dependent and independent variables at this point.

INTERPRETATION OF DATA

Because of the difficulty in observing the embryos at the exact stage of development desired, the answers to some of the questions below will vary greatly. For this reason no attempt will be made to give "pat" answers. The teacher is referred to the references suggested in this guide as well as any other reference on embryology. Just about any Biology text has a section on embryology.

SAMPLE GRAPH:



EMBRYOLOGY: THE DEVELOPMENT OF THE CHICK: STUDENT'S NOTES

PROBLEM: To study how living things begin.

INVESTIGATION 1

BACKGROUND INFORMATION: To learn some of the basic skills necessary for studying the embryonic development of the chicken.

During the course of your study of the embryonic development of the chick, you will be required to carry out various skills. For example you will be required to learn how to remove an embryo from an egg, measure and weigh it and then preserve it. We will then be required to make graphs to help explain our date. Before we begin our actual study of the chicken egg, we must first learn how to use weighing instruments as well as how to measure, using the metric system.

DESIGN FOR COLLECTION OF DATA: Follow the instructions given under Design A and Design B.

DESIGN 1: - Weighing Skills: The purpose of the following exercises is to enable you to become familiar with an OHAUS HARVARD TRIP BALANCE, and an EQUALARM BALANCE, and to allow you to develop the necessary skill in using them. Since we will be using these balances frequently, to weigh the embryos it is worth spending time now to learn their use.

Activity A Ohaus Harvard Trip Balance

A flat and level surface should be selected on which to use the balance. On a flat surface a perfect balance should be obtained, when the rider is set at the zero mark.

If the scale does not balance exactly at zero, there are two balance nuts on the front of the beam to make necessary corrections. When the correct balance has been restored the nuts should be locked against each other. The zero balance should be checked periodically (Why?)

Instructions for Weighing

1. After the zero balance has been obtained, the specimen to be weighed is placed on the left platform of the balance.
2. The riders are then moved to a position which will restore the balance.
3. The lower rider is moved to the right until the first notch is reached which causes the right platform of the scale to drop.
4. The lower rider is then moved back one notch which should cause the right platform to rise.
5. The rider is then moved to the right until the scale is brought into balance.
6. The balanced position is determined by observing the swing of the pointer.

A swing of an unequal number of divisions to the right and left across the dial indicates that the scale is balanced. The weight is read by adding the amount on the beams.

NOTE: Substances to be weighed will, in some cases exceed the beam capacity. When this occurs, weights are placed on the RIGHT PLATFORM until the weight of the specimen is brought within the beam capactiy. The final balancing can be done by manipulating the riders on the beam. The weight of the specimen now becomes the combined total of the weight on the right platform and the beam. Using the above information weigh the following items (record your weights to the nearest tenth).

1. a Canadian penny
2. #5 rubber stopper
3. 50 ml. beaker
4. watch glass
5. test tube and stopper
6. wooden cube

Activity 3 Equalarm Balance

This balance must be placed on a flat surface also. Make sure that the pans swing freely and that the pointer does not rub against the support. A perfect balance is obtained when the pointer swings the same distance on either side of the center of the scale. MARK THIS POINT ON THE LEFT ARM WITH A PENCIL. DO THE SAME WITH THE METAL CLIP ON THE RIGHT ARM. The perfect balance should be checked periodically. (A) Now with your balance adjusted and a set of beads, find the weight of the following objects to the nearest bead:

1. A Canadian penny
2. glass tubing
3. two gram weight
4. glass slide

(B) We have weighed the objects above, to the nearest bead. We may wish to weigh objects to a fraction of a bead. By using the rider on the right arm of the balance we can measure to a fraction of a bead. Place one bead on the left pan and move the rider on the right arm, from the mark made earlier, until the balance point is obtained. MARK THE POSITION OF THE RIDER ON THE ARM. Now make marks on the arm, dividing into 10 equal spaces, the distance between the 0 bead and the one bead position. Each mark represents an interval of 0.1 beads on the scale.

Measure each of the above objects (in A) again using the rider. Compare the precision of the balance when the rider is used to when it is not used. To find out how uniform or standard the beads are, place an equal number of beads in each pan, and adjust the rider until they are balanced.

(C) Because we will be working in grams, it is necessary to make a conversion from beads to grams. To do this follow the instructions below:

1. Place a one-gram weight on the left pan of your balance.
2. Using your beads and rider, attempt to find the number of beads that are equivalent in weight to 1 gram.

RECORD THIS INFORMATION FOR FUTURE REFERENCE.

3. In order to convert the rider scale on the right arm, from beads to grams.

Use the information from number two to find the number of grams that is equal to 0.1 beads. Record this information for future reference.

Each mark on the scale would now represent an interval in grams. It would be wise to repeat section C again, IF TIME PERMITS, so that accuracy may be insured.

Weigh the following: RECORD YOUR WEIGHT IN GRAMS.

1. Canadian penny
2. Canadian dime
3. Canadian quarter
4. American penny
5. American dime
6. American quarter

DESIGN 2: Measuring Skills: Metric System.

Read the following information on the Metric System of Measurement and carry out the exercises that follow it.

In the late eighteenth century the variety of measurement systems in use and the inconsistent bases for the units were hampering both the work of scientists and the interchange of information between scientists of different nations. Devised by a group of scientists in France, a system was adopted by the International Bureau of Weights and Measures in 1875. This system has three major advantages: (1) it is universally used in scientific work and is the language of scientific measurement throughout the world; (2) it is a decimal system compatible with our base-ten number system; (3) it has consistent relationships between the units of length, volume and mass. This system is known as the metric system (metric means measurement). We will use this system in this course.

In the metric system the unit of length is the meter. It was chosen for its convenient length and was defined to be one-millionth of the distance from the equator to the north pole at sea level. Since the art of measurement was not so highly developed in 1875 as it is now, and since the earth has never actually been measured directly, the meter is only approximately this length. To guarantee that this unit could be faithfully reproduced, two marks were inscribed on a rod made of an alloy of platinum; the distance between these two marks was established as the standard meter. The original rod is kept in a vault at Sevres, France, and copies of this standard, called secondary standards, are kept in many countries. One such copy is in the Bureau of Standards in Washington, D.C. The latest method of describing the length of the meter is in terms of the wavelength of light from the element krypton. If the origianl rod were lost or destroyed it could be reproduced to an accuracy of better than one part in 100,000,000 from this information.

TABLE

PREFIX	ABBREVIATION	MULTIPLYING FACTOR	EXPONENTIAL NOTATION
mega-	(none)	1,000,000	10^6
kilo-	km	1,000	10^3
deci-	dm	1/10 or 0.10	10^{-1}
centi-	cm	1/100 or 0.01	10^{-2}
milli-	mm	1/1000 or 0.001	10^{-3}
micro-	um	1/1,000,000 or 0.000001	10^{-6}

The meter, which is slightly longer than the English yard with which you are familiar, is divided into smaller, sometimes more convenient units of length. Latin prefixes are used with the word meter to indicate one-tenth of a meter (deci-meter); one-hundredth of a meter (centimeter); one thousandth of a meter (millimeter); and so on. A useful term of information is the fact that 2.5 centimeters are about 1 inch.

Other prefixes, derived from Latin and Greek words, are used to designate larger and smaller units. The units of the meter are summarized in the table on page one along with the proper abbreviation, the multiplying factor, and the exponential notation.

Other units have been designated to describe very large or very small quantities, such as 10^9 or 10^{-12}, but we will not have occasion to use them in this course. Actually there are very few people who have any real idea of what the actual number of things represented by one million would be.

As stated earlier, the metric system has the advantage of consistent relationships between the units of length, volume, and mass. The standard unit for measuring volume in the metric system is the liter, which is approximately equal to one decimeter on each side (1 dm^3 or one cubic decimeter). The same prefixes are used with the liter as with the meter. A deciliter (dl) is one-tenth of a liter; a centiliter (cl) is one-hundredth of a liter; and a milliliter (ml) is one-thousandth of a liter. It is convenient to know that about 20 drops of water from a medicine dropper are required to make one milliliter. Other liquids may have different sized drops.

You may have noticed that one cubic centimeter (1 cm^3), which is also equal to one-thousandth of a cubic decimeter, would have the same volume as one milliliter.

The third fundamental unit in this system is the gram (g). It is defined as the mass of one cubic centimeter of water. The same prefixes we have already studied may be applied to multiples or fractions of grams. Thus, a decigram (dg) weights 0.1 gram; a centigram (cg) equals 0.01 gram, and a milligram (mg) equals 0.001 gram. It is convenient to use the kilogram (kg), which equals 1,000 grams for measuring large masses. A kilogram weights slightly more than a two-pound mass.

The gram is a measure of mass. Although the word mass may be strange to you, the concept of mass is not. We will discuss it when we begin to work with and measure the masses of objects. Mass is related to weight as you have known and used it.

To assist you in imagining the magnitude of these new units, let's consider a few comparisons. Most sugar cubes measure approximately one centimeter on a side; therefore, one cubic centimeter, or one milliliter of water has a mass of one gram. It will be most helpful to you throughout this course if you fix this value in your mind. If this is true, then what is the mass in grams of one liter of water? Remember that one liter is equal to 1000 milliliters.

One more unit of measurement must be mentioned. It is the temperature scale called the Celsius (C) or centigrade scale. It is used in science in preference to the Fahrenheit (F) scale. The zero point on the Celsius scale is set at the freezing point of water and 100°C is placed at the boiling point of water. Thus 0°C = 32°F and 100°C = 212°F. More will be said about temperature and its measurement later.

SUPPLEMENTARY INFORMATION: THE METRIC SYSTEM

Table of Lengths	Table of Weights
10 millimeters (mm) = 1 centimeter	10 milligrams (mg) = 1 centigram
10 centimeters (cm) = 1 decimeter	10 centigrams (cg) = 1 decigram
10 decimeters (dm) = 1 meter	10 decigrams (dg) = 1 gram
10 meters (m) = 1 dekameter	10 grams (g) = 1 dekagram
10 dekameters = 1 hectometer	10 dekagrams = 1 hectogram
10 hectometers = 1 kilometer (km)	10 hectograms = 1 kilogram (kg)

The most common prefixes, used in the metric system, are given below, with their meanings:

milli - one-thousandth of
centi - one-hundredth of
kilo - one thousand times

A milliliter is a very small length, about equal to the thickness of a wire of a paper clip. A centimeter is a little less than one-half an inch, and a meter is a little longer than a yard.

We can use the above information to help us solve problems dealing with metric measure.

1. Measure the following items in the units indicated:
    1. a piece of glass tubing (cm)
    2. the diameter of a rubber stopper (mm)
    3. the length and width of Nuffield Biology Text I (dm)
    4. the thickness of Text II (mm)
    5. Draw a rectangle 3 cm x 6 cm

2. Express the following measures in the units indicated:

4 cm.______________(mm)   3000 mm______________(m)
84 mm.______________(cm)   8 mm______________(cm)
284 cm.______________(m)   92 cm______________(mm)

3. Evaluation Exercise

You will be given a group of tiles that have been cut into various shapes. You will be required to carry out the measurements and calculations as instructed below. EACH TILE HAS A NUMBER ON IT. THE NUMBER CORRESPONDS TO THE NUMBER OF THE INSTRUCTIONS BELOW.

1. Measure the length in cm.______________
   Measure the width in mm.______________
2. Measure the blackened end of the tile
    a. Measure the length in mm.______________
    b. Measure the width in mm.______________
3. Measure the length in cm.______________. Express this length in meters______
   Measure the width in mm.______________. Express in centimeters______________
4. a. Measure the length in cm. ______________
    b. Measure the width in mm.______________. Express the width in cm.______

5. a. Measure the length in cm.________________
   b. Measure the width in cm.________________
   c. Measure the height in mm.________________ Express in cm.____________

DURING THE FOLLOWING FEW WEEKS WE WILL BE ATTEMPTING TO GAIN SOME INSIGHT INTO THE EMBRYONIC DEVELOPMENT OF THE CHICKEN. TO ACCOMPLISH THIS YOU WILL BE REQUIRED TO STUDY THE CHICKEN EMBRYO AT VARIOUS STAGES OF DEVELOPMENT. FOR THIS PURPOSE THE STUDY WILL BE BROKEN UP INTO A SERIES OF SUB-PROGRAMS. IN THIS WAY THE INVESTIGATION WILL PROCEED IN A SMOOTH MANNER. YOU MUST FOLLOW THE INSTRUCTIONS FOR EACH SUB-PROBLEM. QUESTIONS WILL BE GIVEN TO YOU AT THE END OF EACH INVESTIGATION. THESE MUST BE ANSWERED SATISFACTORILY BEFORE YOU PROCEED TO THE NEXT ONE.

INVESTIGATION 2

SUB-PROBLEM: To locate and identify the parts of a hard boiled egg (Egg A)

BACKGROUND INFORMATION:

1. Read pp 79-82, section 5-1 of "Biology: Text I: Introducing Living Things". Read the pages very carefully. When reading the instructions on page 80, "How to open an egg", imagine that you are a surgeon, working carefully and skillfully and at all times trying not to destroy other tissue.

2. Study the diagram on the top of page 81. These are the parts you will be trying to locate.

3. Make important notes about the egg in your notebook.

DESIGN FOR COLLECTION OF DATA:

Materials: incubator, forceps, pencil, 1 hard boiled egg, petri dish, table knife, paper towels, scissors, probe.

NOTE: the student will be expected to provide for himself those materials that are underlined.

1. Place the egg in the petri dish that has crumpled paper towel in it to prevent the egg from rolling about.

2. Very carefully crack the eggshell near the blunt end of the egg. Do not destroy the outer membrane which is directly below the shell. Slowly remove the shell from the blunt end. Note the air sac.

3. Cut away the outer membrane at the air sac. With your probe gently lift the inner membrane from the surface of the white. Cut away this membrane.

4. Quickly remove the balance of the shell from the white of the egg but not so quickly as to lift the white of the egg with the shell.

5. Use the table knife to cut the egg in half along its length. Try to see the coiled strand of white that supports the yolk extending out from the yolk along the length of the egg.

6. Note the position of the yolk with respect to the white of the egg. Are the yolks of other eggs in the same position? Note the differences in color of the yolk between that of one egg and that of another.

OBSERVATIONS: Make a diagram of an egg. Locate and label these parts:

1. shell
2. outer membrane
3. inner membrane
4. air space
5. blastodisc
6. yolk
7. chalazae - strand of white supporting the yolk
8. egg white

INTERPRETATION OF DATA:

1. How many layers of egg white can you see?

INVESTIGATION 3

SUB-PROBLEM: To locate and identify the parts of a fresh egg (Egg B).

BACKGROUND INFORMATION: Re-read pages 80 and 81 in Nuffield Text I.

DESIGN FOR COLLECTION OF DATA:

Materials:

petri dish
paper towel
forceps
medicine dropper
saline solution
1000 ml beaker
hand lense
1 fresh egg - to be supplied by student.

1. Look at the position of egg B in the incubator. Is the date facing up or facing down? Remove the egg from the incubator and place it in the petri dish--never changing the position of the date on the egg. Place a piece of crumpled newspaper in the dish to keep the egg warm and prevent it from turning when you are working with it.

2. With a pencil, lightly trace an oval that will be the approximate size of the window you intend to make in the shell. Tap gently with the blunt end of the forceps to crack small pieces of the shell. Remove these pieces and place in the beaker to be disposed of later. Draw off some of the albumen with the medicine dropper and dispose of in the sink. Flush the sink drain by allowing water to run slowly and steadily. Do not allow albumen to flow over the sides of the window as you increase the size of the window to meet the pencil marks.

3. Examine the yolk with the hand lense. In the observation section make a top view of the yolk and draw the location of any variation that you see in the color or texture of the yolk. If you see no variation do not make a diagram.

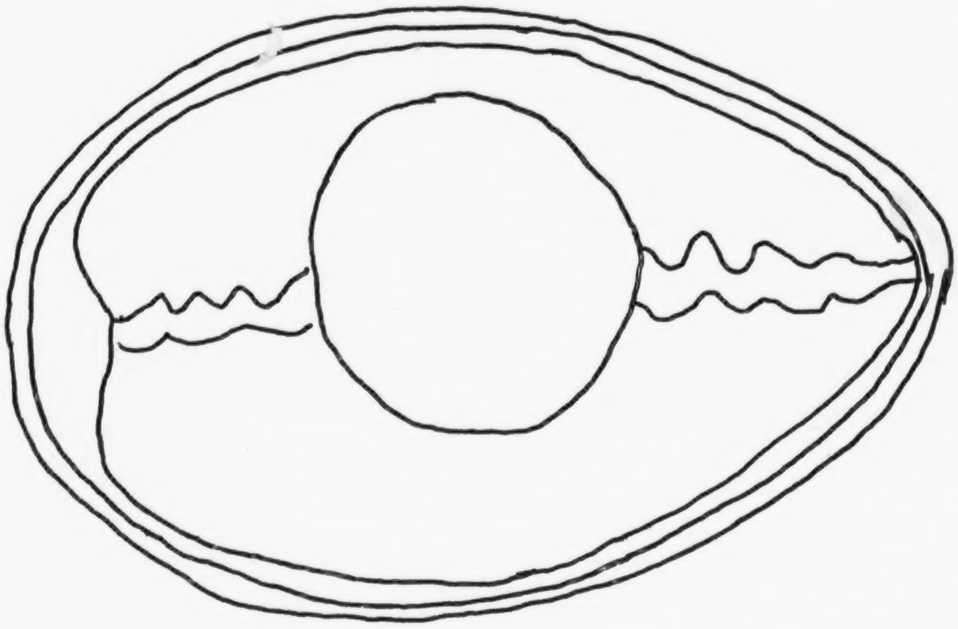
4. Remove the paper towel from the petri dish. Hold your thumbs on either side of the window and gradually pull apart the two ends of the egg shell and let the contents of the egg drop gently into the petri dish. Do not break the yolk.

5. Now examine the white. Is its appearance the same all through? Can you see that at either end there are strands of tougher white matter? These support the yolk so that it can turn around whichever way the egg is turned, like a ship's compass.

6. Look inside both ends of the broken shell. In the Interpretation of Data answer the following questions.
    a. At which end of the egg shell is the membrane not closely attached to the shell? (blunt end or pointed end).
    b. What occupies the space between the inner and outer membrane, at the end (in a.)

7. Before you leave the room your work area must be CLEAN. All egg shells and paper towels are to be put in the garbage pail. The soft parts of the egg may be placed in the container provided. The petri dishes, probes, and forceps must be washed and dried. In order to ensure that you have time to complete the clean-up, it will be necessary to start about five minutes before the period ends.

<ins>OBSERVATIONS</ins>: Draw a diagram of egg B, similar to the one below and label the following parts: <ins>shell</ins>, <ins>outer membrane</ins>, <ins>inner membrane</ins>, <ins>albumen</ins>, <ins>chalaza</ins>, <ins>yolk</ins> and <ins>blatodisc</ins>.



<ins>INTERPRETATION OF DATA</ins>: Using the reference materials in the room and in the library, find out what are the functions of each of the structures of the egg.

INVESTIGATION 4

SUB-PROBLEM: To locate and identify the parts of a fertile egg.

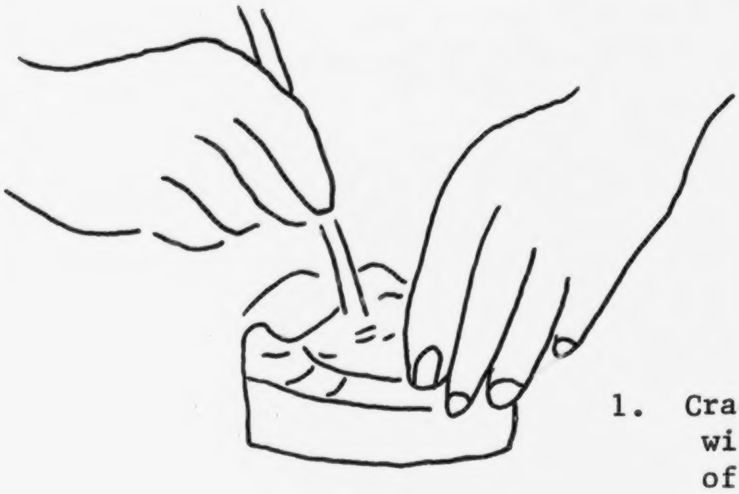
BACKGROUND INFORMATION:

1. Using the reference material available to you attempt to find information concerning the differences between asexual and sexual reproduction in animals.

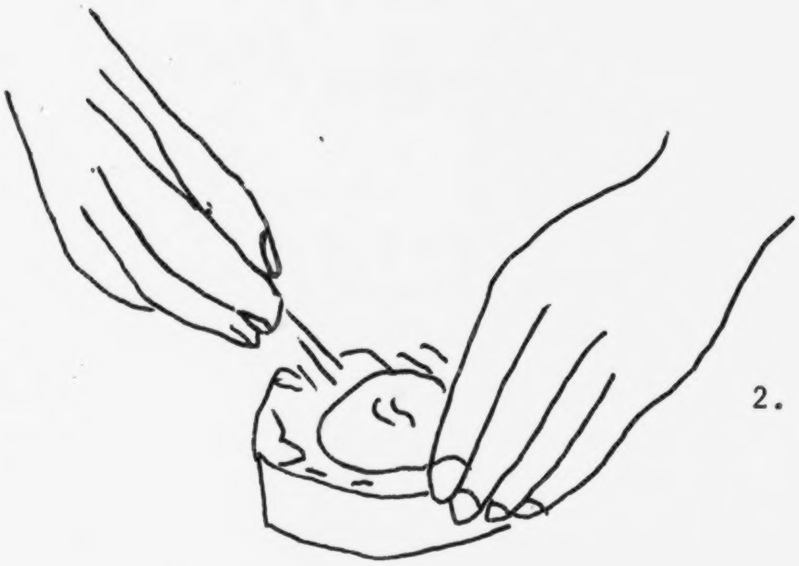
2. Accompanying this investigation a diagram of the female (♀) reproductive tract of a chicken is given. By the use of available resource material label the diagram and tell what each part does in the production of an egg.

3. Follow the instructions below for opening eggs.

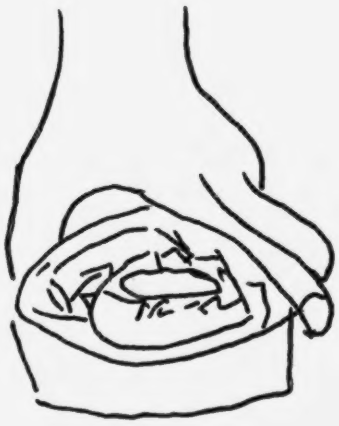
Adapted from Nuffield Text I



1. Crack the egg with the handle of the scalpel.

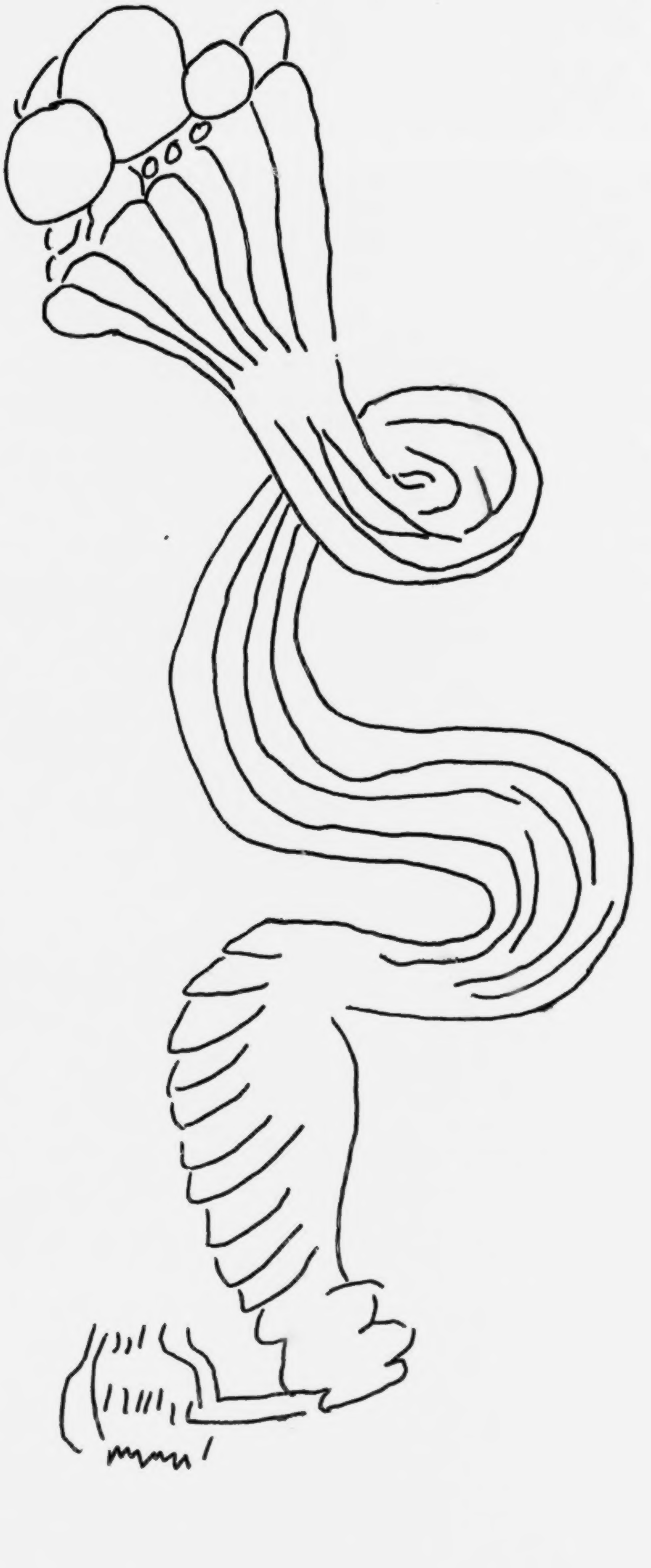


2. Using forceps carefully pick off bits of shell.



3. A window has been made in the shell.

DIAGRAM OF ♀ (FEMALE) REPRODUCTIVE TRACT



Incubating Eggs

In our study we found that a fertile egg contains a living embryo. This is to say each one contains a living chick which needs to breathe, feed and be kept warm. In addition it must be kept moist. A hen sitting on her own eggs keeps them warm (at a temperature of about 38°C) and turns them several times a day. The moisture from her body keeps the eggs in a damp atmosphere.

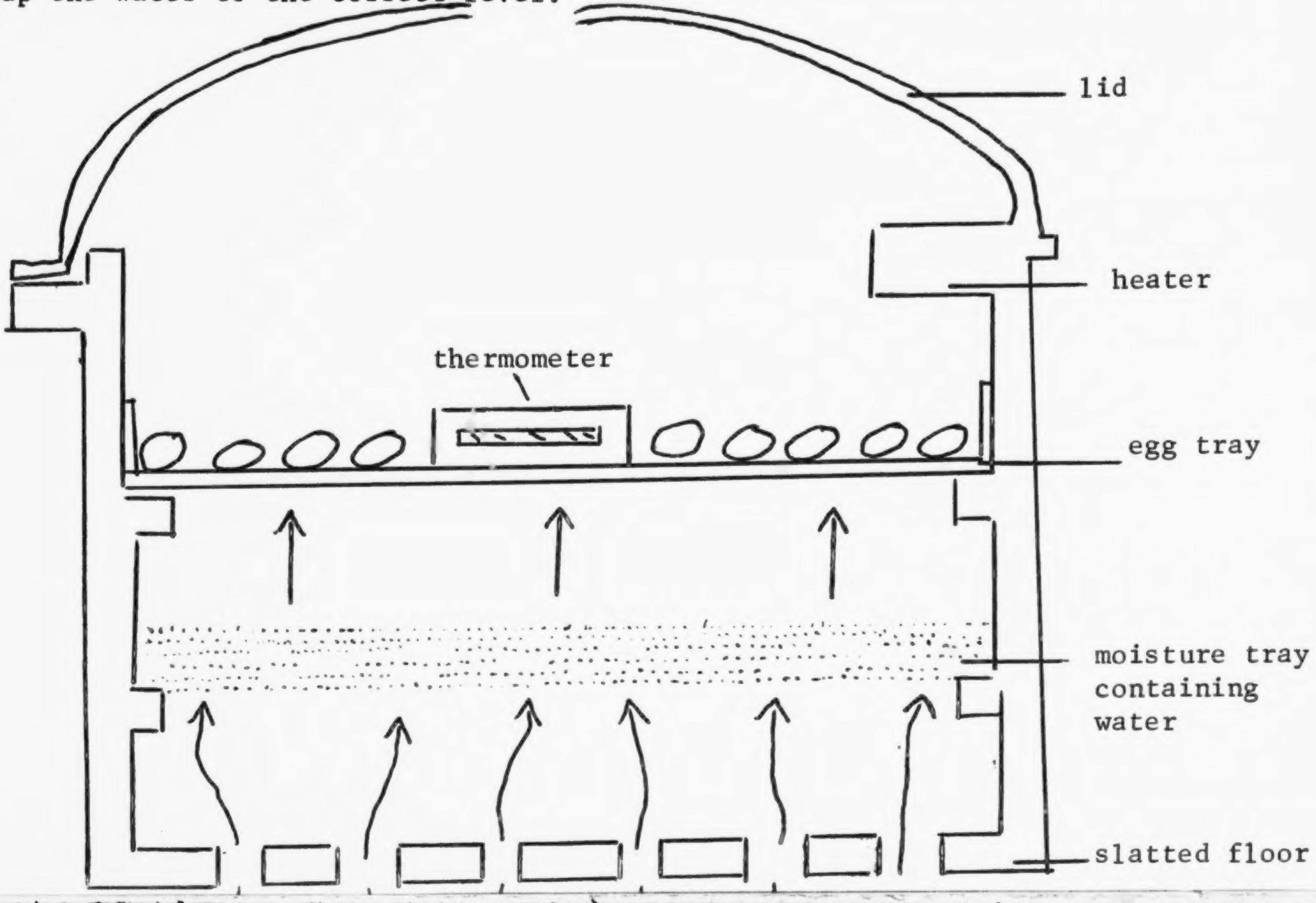
If you look at the diagram of an incubator below you will notice that it is designed to copy the conditions which the hen provides for hatching eggs.

From the observations which you made on the structure of the egg, can you answer these questions:

a. Why should an egg be turned at least twice a day?
b. Why should there be a current of fresh air passing through the incubator?
c. Why do the eggs need to be in a moist atmosphere?
d. When you take an egg from the incubator to examine the embryo, why should you be careful to hold it up in the same way as it was in the egg tray?
e. Why is the incubator kept at 38°C?
f. Why should you wrap the egg in tissue paper or cotton wool before transferring it to the place where it is going to be examined?

Section Through an Egg Incubator
The arrows show how the air flows through the incubator.
Here are some of the rules which you should follow when looking after eggs in an incubator:

1. Each egg should be marked on one side, with the date it was put in the incubator.
2. Every morning and afternoon the eggs should be turned by rolling them over sideways with the tips of the fingers; if the marked side was on top, they should be rolled over so that it is now underneath. Wash your hands before turning the eggs.
3. Every morning and afternoon check the temperature. It should be 38°C.
4. Twice a week, distilled water should be added to the moisture tray to bring up the water to the correct level.



DESIGN FOR COLLECTION OF DATA

MATERIALS

petri dish
newspaper
forceps
medicine dropper
scissors
hand lense
warm saline solution
1000 ml beaker
metric ruler
filter paper
compass
microscope
10% formalin solution
preserving jar

1. Note the position of the egg in the incubator and place in the petri dish in the same position. Support the egg with crumpled newspaper.

2. Pencil the shape of the window just larger than the size of the yolk beneath the shell. You will have to approximate this size based on your experience of the size of the yolk in eggs A and B.

3. Make a window in the egg trying not to break the shell membrane beneath. Now open the shell membrane and draw off albumen with the medicine dropper until the upper portion of the yolk is uncovered. Great care must be taken that the yolk is not broken.

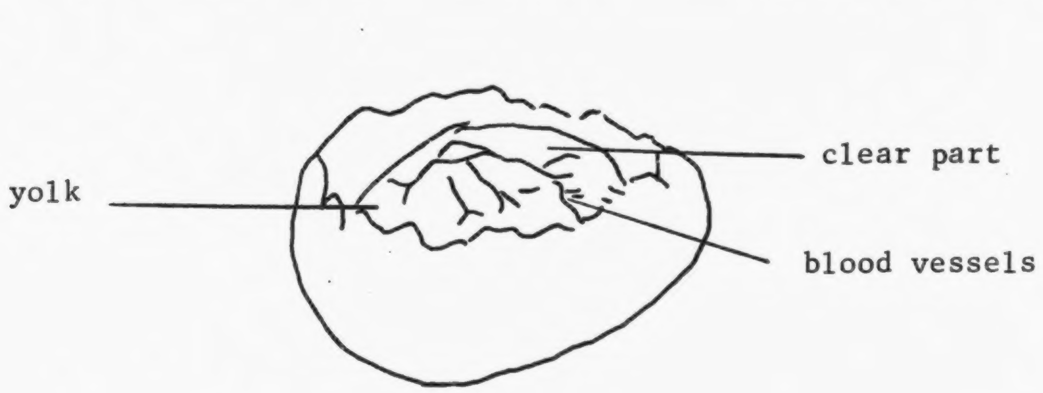
4. The embryo should be on top of the yolk. If it is not, gently pushing with the medicine dropper may rotate the yolk until the embryo is on top--but great care must be taken that the yolk is not broken.

5. With a pipette draw up some warm salt solution and drop a little on to the clear part in the middle of the yolk.

6. Under a lens you may be able to see that there is a tiny chick embryo with a heart that is beating. You may also see blood vessels extending over the yolk from the embryo. Draw a diagram of the yolk, showing the proportional sizes of the embryo and the yolk sac.

7. Using a hand lense examine the embryo. Locate the heart by looking for a pulsating movement. Record how many pulsations there are per minute, by having one person count them quietly to himself while a second person, the timer, tells him when to begin and to stop counting.

8. Using a metric ruler measure the diameter of the yolk sac.



OBSERVATIONS:

1. Record the number of pulse beats per minute, in your notebook.
2. The embryo you have been observing is approximately 24-48 hours old. Draw and label the following parts of the embryo.
   (a) yolk (b) yolk sac (c) embryo

INTERPRETATION OF DATA:

1. What differences did you note between egg C and egg B?
2. What occured to egg C that did not occur to egg B?
3. Are the eggs you buy in the store like egg B or egg C?
4. Why must the egg be kept in the same position when removed from the incubator?

INVESTIGATION 5

SUB-PROBLEM: To study the development of the chick embryo.

BACKGROUND INFORMATION: Re-read your INSTRUCTIONS FOR OPENING EGGS, and weighing skills.

DESIGN FOR COLLECTION OF DATA: To study the development of the chick embryo, you will be required to open eggs at various stages of development. In order to accomplish this, the design will be broken down into five (5) parts.

NOTE: ALL OBSERVATIONS WILL BE RECORDED IN THE CHARTS AND DIAGRAMS THAT FOLLOW the design. Students will be required to record any changes or additions made to the designs that follow.

MATERIALS: listed here are to be used for each of the designs.

evaporating dish
forceps
medicine dropper
scissors
hand lense
needle
preserving jar
saline solution
metric ruler
pan balance and weights
filter paper
compass
microscope
formalin

DESIGN 1: THE 3½ DAY EMBRYO

1. Note the position of the egg in the incubator and place in the finger bowl in the same position. Support the egg with crumpled paper towel.
2. Pencil the shape of the window just larger than the size of the yolk beneath the shell. You will have to approximate this size based on your experience of the size of the yolk in eggs A and B.

3. Make a window in the egg, trying not to break the shell beneath. Do this by gently cracking the egg with a blunt object in the middle of the window. Now use your needle to gently pry off bits and pieces of the shell. Use your forceps to help you do this.

4. Once the shell has been removed carefully cut away the shell membranes. Be careful not to cut to deeply; you may cut the embryo or yolk.

5. Now gently pull the membrane away. Do this slowly because sometimes the embryo sticks to the membrane.

6. The embryo should now be on top of the yolk. If it is not, gently pushing with the medicine dropper, rotate the embryo until it is on top. BE CAREFUL.

7. Is the embryo alive? How do you know? Count the number of heart beats per minute and record this in the observations.

8. Squirt a little saline solution on the embryo and note what happens.

9. Using a metric ruler measure the diameter of the yolk sac. On filter paper draw a circle slightly less than the diameter of the yolk sac. Make a second circle with a diameter about ¼ inch larger than the inner circle. Cut out the ring you have drawn and place it over the edges of the yolk sac.

10. Grasp the ring and the edge of the membrane of the yolk sac with forceps. Clip the membranes with the scissors all the way around the ring of filter paper. Do not break the yolk beneath the yolk sac, but if you do, continue your job just the same. Slowly lift the ring, membrane and embryo away from the yolk as you cut. Place the ring, membrane, and embryo in a petri dish of warm saline solution. Observe the embryo under your microscope.

11. In your observation you have been given four diagrams of chick embryos. Which of these four diagrams most closely resembles the embryo you have just disected out? Using the date given to you on the egg shell make a title for this diagram of how old the chick embryo is. (Example: 3½ day old Chick Embryo).

12. By observing your chick embryo and by the use of reference books in the classroom, label your diagram of the embryo with the following labels: hind brain, mid brain, fore brain, eye, tail, leg bud, wind bud, yolk connection, heart.

13. Once you have labelled your diagram obtain a pan balance and weights at the front of the room. Using the pan balance and weights, weigh the chick embryo and record this in your observation. Be sure to put the embryo on a piece of paper before weighing. Your instructor will show you how to use the pan balance for weighing.

14. Having weighed the embryo, now measure its length. Do this by stretching a piece of string from the embryo's beak around down its backbone to the tip of its tail. Cut the string at the tail and measure the string's length to the nearest millimeter. Record this in your observation.

15. Use a Metric ruler and measure the diameter of the chick's eye. Record this in your observations.

16. Once you have completed all your observations and measurements, place your embryo in a preserving jar which contains formaline. Label this jar with your name, date, object (chick embryo) and the age of the embryo.

17. Now follow the following steps to clean up.

    (a) Return all equipment to the place from where it came. Make sure that everything is CLEAN and DRY.

    (b) Place all shells and paper towels in the waste basket.

    (c) Place egg yolks and egg whites in the container provided, for later disposal.

18. This same method (1-17) will be used, for the study of the remaining three eggs, with some changes.

19. NOTE: Place all observations and data in the correct charts and diagrams under observations.

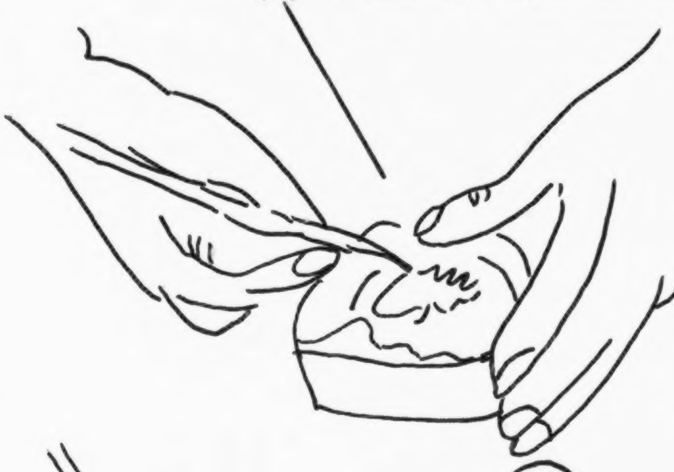
DESIGN 2: The Five Day Embryo

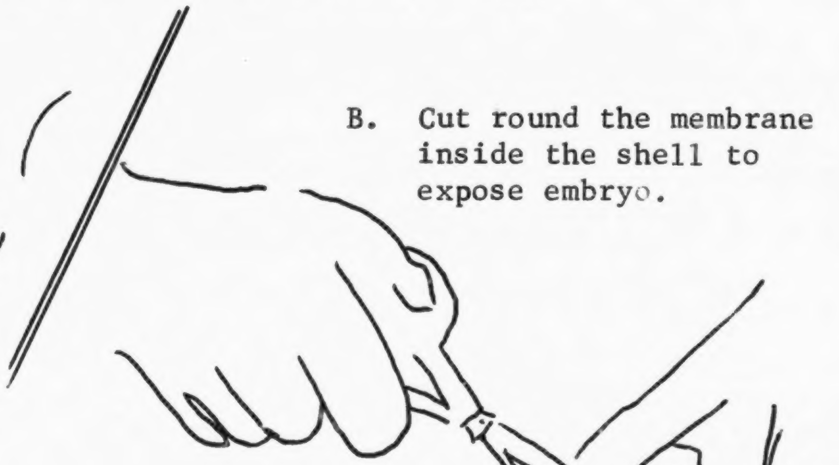
1. Follow the instructions for removing the embryo, as you did for Design A.

2. If you have difficulty in removing the embryo as outlined in 9 and 10 of Design A, you may use the following techniques. NOTE: USE THIS TECHNIQUE ONLY IF THAT IN DESIGN A DOES NOT WORK.

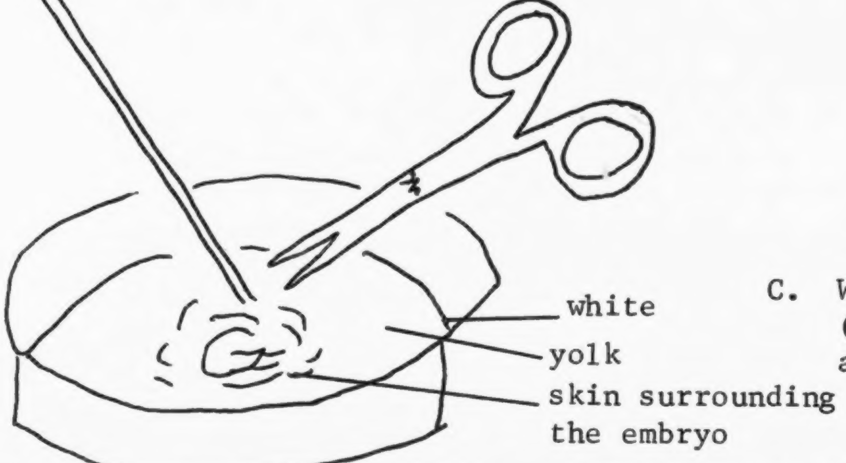
A. Using the procedure outlined below, try separating an embryo from the yolk and white when it is five days old.

    (1) Pick off bits of shell to make a window in the egg.





B. Cut round the membrane inside the shell to expose embryo.



C. With forceps lift the skin (membrane) surrounding the embryo and cut it away.

3. The yolk by this time will have become rather watery and the embryo will be enclosed completely in another skin (the omnion).

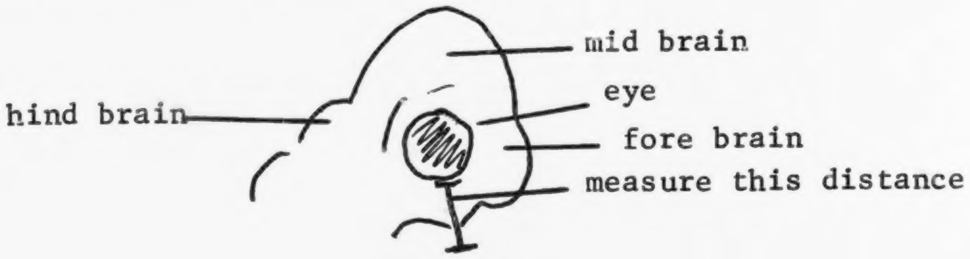
4. With a hand lense look at one large blood vessel spreading over the yolk. Note whether blood is moving in the yolk or not.

5. After the embryo has been removed from the yolk, clean it as much as possible, by removing the membranes with scissors and forceps. You will probably need to wash the embryo in several rinsings of water to clean it of yolk and white.

6. You should be able to make our the various structures more clearly. Compare the size of the eye with the size of the head. Is the eye larger than that of a 3½ day old embryo? Can you see that the eye is covered with black pigment, except for the central part which is the lens? The wing and leg buds are just visible in a 3½ day old embryo. Have they grown larger? Can you make our the beginning of the beak? Can you see the heart beating?

7. Follow the instructions from Design A for recording your observations and measurements made.

   NOTE: In addition to measuring the diameter of the eye, now you can measure the distance from the tip of the beak to the outside of the eye as follows:



8. Place the following labels on the diagram that most resembles your specimen: beak (starting of), hind brain, mid brain, fore brain, eye, tail, leg, yolk connection, wing, heart.

9. Follow the clean up instructions given in Design A.

DESIGN 3: The Seven Day Embryo

1. Follow the instructions for removing the embryo, using the methods outlined in Designs A and B.

2. The embryo will still be attached to the yolk by blood vessels, so you will have to cut these with scissors in order to free the chicken completely. The chick dies almost immediately as the egg is broken so will not feel anything now. The embryo is still curled up. Can you make out the following structures: three "fingers" on wing, feather tracts. The small white dot which you may be able to see on the tip of the beak is the egg tooth by means of which the chick break through the shell when it is ready to hatch, three webbed toes, yolk connection, ear, eye (compare the size of the eye with the size of the head). PLACE THESE ON THE APPROPRIATE DIAGRAM.

3. Follow the previous instructions for recording observations and measurements made.

4. Clean up as instructed by your teacher.

DESIGN 4: The Ten Day Embryo

1. Follow the instructions for removing, measuring and weighing the embryo, that have been given in the previous designs. Also follow the instructions for recording observations, measurements and clean-up that have been previously given.

2. For the first time the embryo looks quite "bird-like". The beak is well formed and toes are quite distinct. Find the following parts and label them on the appropriate diagram: feather tracts, tail feathers, ear, nostril, egg tooth, yolk connection, eye. Look at the eye and see if you can make out these parts: upper lid, nictitating eye lid. Most birds have a nictitating membrane over each eye. It is really a third eyelid which protects the eye of the bird from dust and the glare of the sun when it is in flight. Look at your partner's eye. Right in the corner, can you see a small piece of pink skin? This is all that remains of the nictitating membrane in human beings.

DESIGN 5: Hatching the Chick

With the eggs left over, go on incubating them. They should start to hatch on the twenty-first day and the actual process of hatching is most interesting to watch. Movements of the chick within the shell cause the head to be jerked forward and the beak upwards. The egg tooth on the beak is now quite large and these movements split the membranes inside the shell and finally crack the shell itself. The chick kicks with its legs and the beak enlarges the hole in the shell. When it first appears the chick looks rather shaggy and damp but its downy feathers soon dry and it is now a fluffy chicken.

It is amazing to think that the single-celled embryo, with which we started the story can develop, in the space of just 21 days, into a day-old chick with feathers and able to peck its own food.

Data will be supplied for 14, 16 and 18 day embryos.

OBSERVATIONS:

NOTE: The observations you made on the embryo (24 - 36 hours old) from investigation E-5 may be useful here.

1. You have been given four diagrams of chick embryos. Refer to accompanying diagrams; match the chick embryo you have disected with the diagram which most closely resembles that embryo. Title the diagram with the embryos age which is obtained by counting from the starting date.

2. Fully label the diagram using the labels given in each design.

3. Design a chart similar to the one below, in order to record and organize your data in a meaningful manner.

AGE	DATE	WEIGHT (GRAMS)	LENGTH MILLIMETERS	DIAMETER OF EYE MILLIMETERS	DISTANCE FROM TIP OF BEAK TO OUTSIDE OF EYE	HEART BEATS PER MINUTE
3½						
5						
7						
11						
14						
18						

4. Using the chart below describing what new organs appeared in each embryo. Also describe any other changes you may have seen in these embryos.

AGE	NEW ORGANS YOU OBSERVED

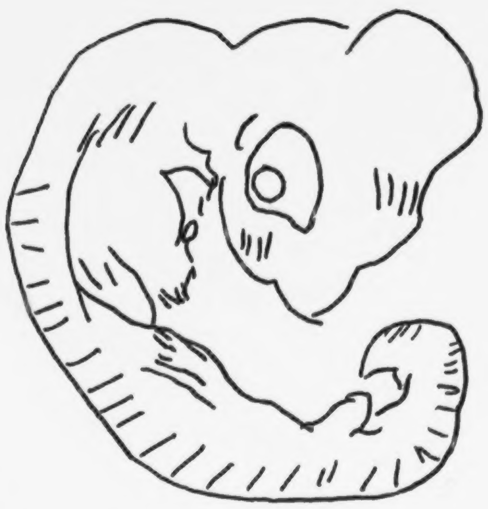
5. Make a written description of the blood vessels going to and from the embryo and to and from the inner membrane. Be sure to note any differences you see in these blood vessels.

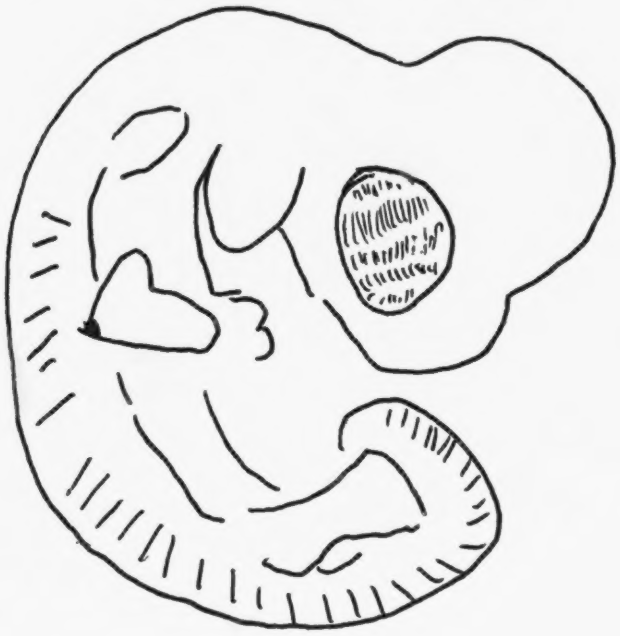
6. There are a number of questions that must be answered in your interpretation of data. These questions are based upon your accurate observations. Be sure to consult these questions as you do your observing.

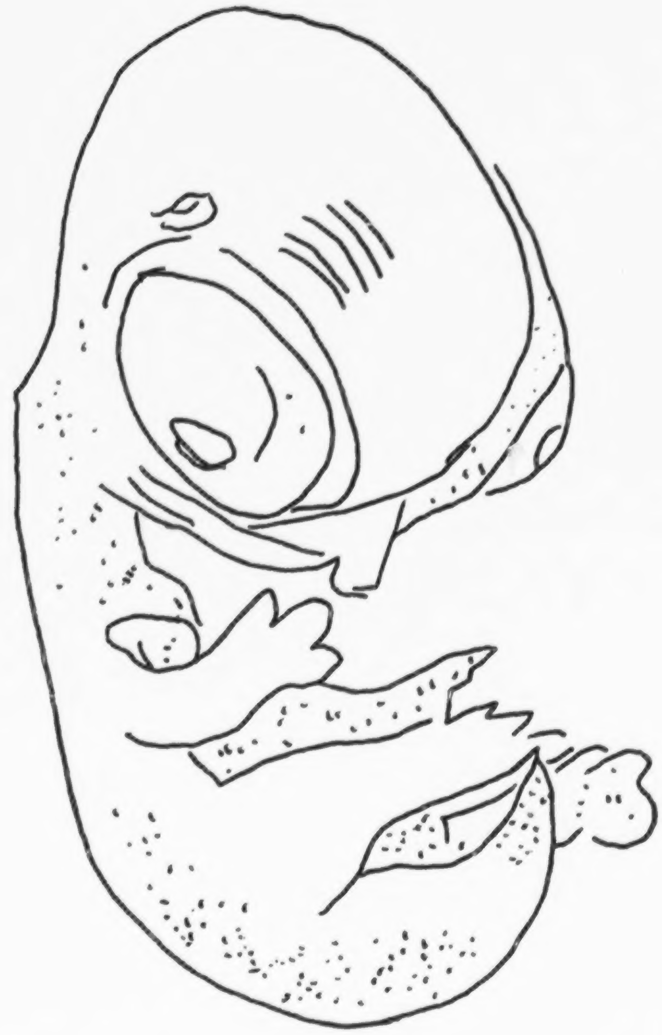
Diagrams to be used for observations in Investigation E-6, Designs A, B, C, and D.

Below you are supplied with four diagrams.

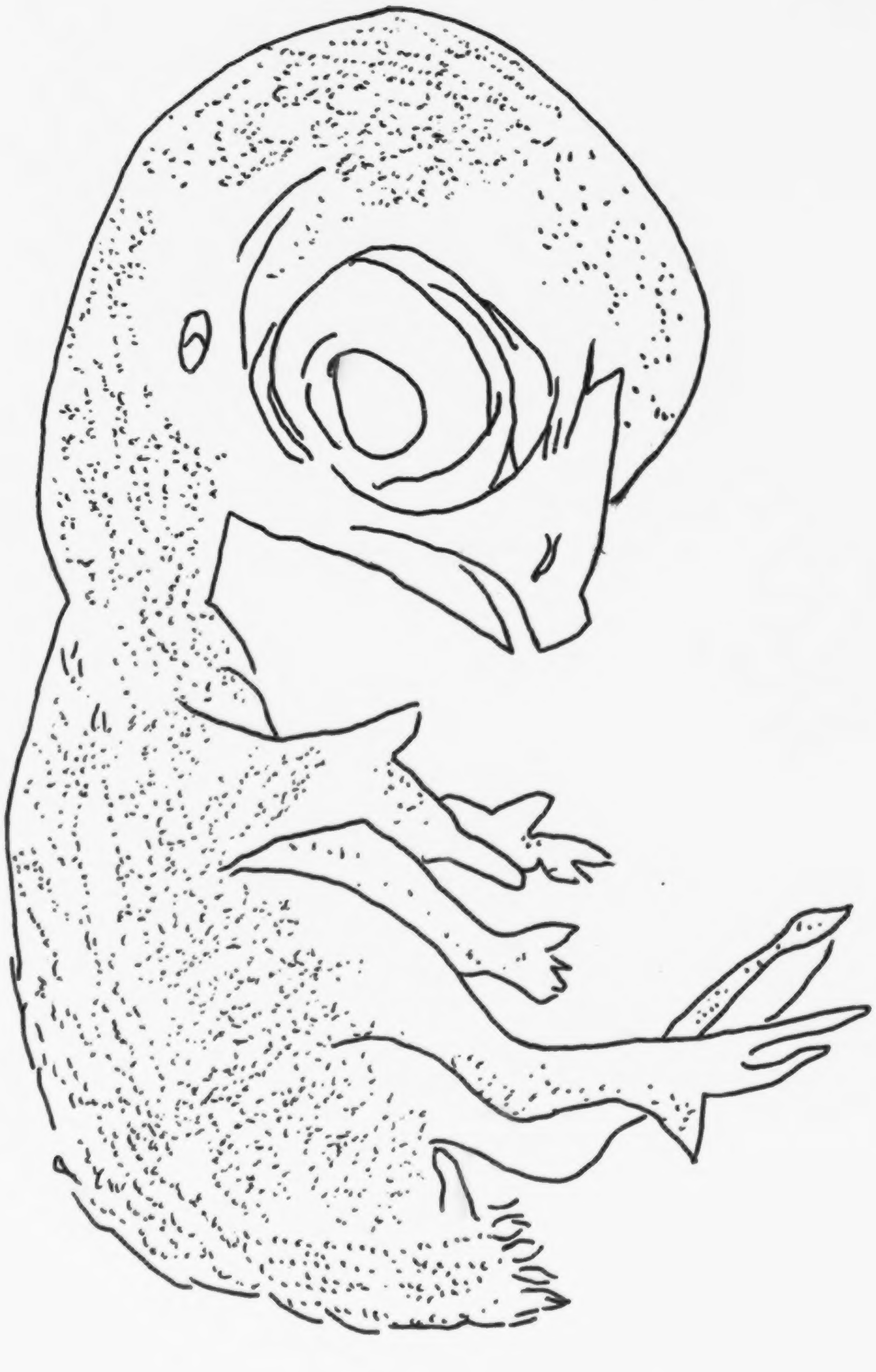
1. Title each diagram with the appropriate design letter and state the age. For example: Design A: 3½ day old embryo.
2. Label all the visible parts you have identified, as instructed for each design.
3. NOTE: DO NOT MISPLACE THESE DIAGRAMS AS THEY WILL BE USED FOR MAKING ANY FINAL ANALYSIS OF CHICKEN EMBRYO DEVELOPMENT.







S - 21



ORGANIZATION OF DATA AND MATHEMATICAL TREATMENT

On the chart given, on the following pages, you are asked to gather all measurements taken by other groups. This information will be put on the blackboard for you to copy. Once this has been done, you will then work out the average weight, length, eye diameter and heart beat for each embryo.

GRAPHICAL REPRESENTATION OF DATA

1. Draw bar graphs or line graphs, as instructed, comparing the following:
    A. Compare age with length of embryo in millimeters.
    B. Compare age with weights of embryo in grams.
    C. Compare age with diameter of eye in millimeters.
    D. Compare age with distance from tip of beak to outside of eye.

2. Note: Draw a different graph for each of the above comparisons.

3. In a brief, concise paragraph describe what each graph represents.

INTERPRETATION OF DATA

1. Describe what changes occured in the following structures at the chick embryo grew older.

    (a) fore brain

    (b) mid brain

    (c) hind brain

    (d) eye

    (e) heart

2. At what age did you first note the following structures?

    (a) wing and leg buds

    (b) ear

    (c) beak

    (d) feathers

    (e) eye lids

    (f) nostrils

    (g) egg tooth

    (h) nictitating membrane

3. Where does the embryo obtain its food from?

4. How does it get the food from this place?

5. Where does the embryo get oxygen from so that it can breathe?

6. How does the oxygen get to the embryo from this place?

7. How does the embryo get rid of carbon dioxide?

8. Why are there two differently colored blood vessels going to and from the embryo?

9. Where do the waste products that are produced by the embryo go?

10. What purpose does the fluid-filled sac, that surrounds the embryo, serve?

11. In which of the following periods does the embryo gain the most weight and the most length?

    days 1 - 3
    days 3 - 6
    days 6 - 9
    days 9 - 12
    days 12 - 15
    days 15 - 18
    days 18 - 21

12. Does the embryo's weight continue to increase as much as its length? Why or why not?

UNIT VI

ECOLOGY

ECOLOGY: 1. TEACHER'S NOTES[1]

Lecture Section

Prior to taking students on a field trip it will be necessary to spend some time in class discussing and making notes on the basic principles in ecology. A general outline of concepts or materials that should be covered is given below.

Many of the topics in this outline may be beyond the level of grade seven. The outline only suggests a number of topics to be discussed or taken up in class. It is up to the teacher to pick and choose those topics which he or she feels they would like taught. The major reference book used in the making of this outline was High School Biology, B.S.C.S. Green Version. This book is recommended as the best reference book for the teaching of the lecture section of this unit. The book, A Source Book for the Biological Sciences is an excellent reference for the laboratory part of this unit. Other texts and reference material for the student and for the teacher are given at the end of this unit. Also listed are a number of films and filmloops which can be used in the teaching of this section.

OUTLINE

Unit VI **ECOLOGY**

A. Introduction

    1. Define, discuss and take up examples of this field of study.

B. Abiotic Factors

    1. Define
    2. Temperature
    3. Light
    4. Water
    5. Gases
    6. Soil
    7. Fire
    8. Other

C. Biotic Factors

    1. Populations
        (a) meaning of
        (b) species, meaning of
        (c) density
        (d) counting of
        (e) fluctuations

---

1. Revised from units developed by Don Hollands, Wayne Phare, and Henry Visscher.

C. 2. Communities

- (a) meaning of
- (b) types of
  - (i) pond
  - (ii) stream
  - (iii) forest
  - (iv) grassland
  - (v) bog
- (c) relationships within
  - (i) neutralism
  - (ii) commensalism
  - (iii) mutualism
  - (iv) parasitism
  - (v) predation
  - (vi) competition
- (d) structure of
  - (i) producers
  - (ii) consumers
  - (iii) food web
  - (iv) food chain
  - (v) pyramids of number, biomass and energy
- (e) succession in
- (f) relationship to biosphere

TEACHERS' REFERENCE LIBRARY

A. These references may be found in most school libraries.

1. Abercrombie, M. C. J. Hickman and M. L. Johnson A Dictionary of Biology.
2. Biological Science: An Inquiry Into Life, Second Edition.
3. Biological Science: Molecules to Man. Blue Version.
4. B. S. C. S. Green Version, High School Biology, Second Edition.
5. Borradaile, et al, The Invertebrata.
6. Brandwein, P. F., R. W. Burnett and R. Stolberg, Life: Its Forms and Changes.
7. Breland, O. P., Animal Life and Lore.
8. Buckshaum, R., Animals Without Backbones, Volumes 1 and 2.
9. Disney, W., Bees and Ants.
10. Fichter, G. S., Snakes and Other Reptiles.
11. Fitzpatrick, F. L. and J. W. Hole, Modern Life Science.
12. Guthrie, M. J. and J. M. Anderson, General Zoology.
13. Haas, R., Enjoy Your Terrarium.
14. Hill, et al, Botany.
15. Jacknicke, K. G., A Guide to Collecting and Culturing Locally Obtainable Freshwater Organisms In the Edmonton Area, February 1968.
16. Lapage, G., Animals Parasitic in Man.
17. McElroy, W. D., et al, Foundation of Biology.
18. Moon, T. J., P. B. Mann and J. H. Otto. Modern Biology.
19. Moon, T. J., J. H. Otto and A. Towle. Modern Biology.
20. Morholt, E., P. F. Brandwein, A. Joseph, A Sourcebook for Biological Sciences.
21. Noson, A. and P. Goldstein, Biology: Introduction to Life.
22. Parker, B. M., Plants and Animals and Us.
23. Reid, G. K. Pond Life, A Guide To Common Plants and Animals of North American Ponds and Lakes.

24. Romer, A. S., Man and The Vertebrates. Volumes 1 and 2.
25. Ross, H. H., A Textbook of Entomology.
26. Salt, W. R. and A. L. Wilk, The Birds of Alberta.
27. Thurber, W. A. and R. E. Kilburn. Exploring Life Science.
28. Trees and Shrubs of Alberta, Department of Lands and Forests, Government of the Province of Alberta.
29. Weeds of Canada, Canada Department of Agriculture.

B. Field Guides and Handbooks

1. Burt, W. H. and R. P. Grossenheider. A Field Guide to the Mammals.
2. Comstock, A. B., Handbook of Nature Study.
3. Nathews and Taylor. Field Book of American Wild Flowers.
4. Murie, O. J., A Field Guide to Animals Tracks.
5. Mitchell, R. T. and H. S. Zim. (Guide). Butterflies and Moths.
6. Palmer, E. L. Fieldbook of Natural History.
7. Peterson, R. T. A Field Guide to Western Birds.
8. Petrides, G. A. A Field Guide to Trees and Shrubs.
9. Zim, H. S. and C. Cottam. (Guide) Insects.
10. Zim, H. S. and D. F. Hoffmeister, Mammals. A Guide to Familiar American Species.
11. Zim, H. S. and A. C. Martin. Flowers. A Guide to Familiar American Wildflowers.
12. Zim, H. S. and H. M. Smith. (Guide) Reptiles and Amphibians.
13. Zim, H. S. and H. H. Shoemaker. (Guide) Fishes.

C. General Reference Books

1. Will Barker, Familiar Animals of America.
2. Will Barker, Winter - Sleeping Wildlife.
3. Lincoln Barnett and Life Editors. Wonders of Life on Earth.
4. Ruth Bartlett. Insect Engineers - Story of Ants.

5. Archie Carr and Life Nature Editors. The Reptiles.
6. Geoffrey Ose. (How and Why Wonder Book) Trees.
7. Elizabeth Cooper. Science in Your Own Back Yard.
8. Elizabeth Cooper. Insects and Plants.
9. Mabel Cuthbert. Spring Flowers.
10. Edmond Dietmars. Reptiles of North America.
11. Harold Deering. An Ant Is Born.
12. Harold Deering. A Bee Is Born.
13. Ruth Dudley. Partners in Nature.
14. Frederick Fitzpatrick. Our Animal Resources.
15. Robert Froman. Spiders, Snakes and Other Outcasts.
16. Bill Gilbert. How Animals Communicate.
17. Delia Goetz. Tropical Rain Forests.
18. Edward Graham and William Van Dersal. Wildlife for America.
19. Robert Hegner. Parade of the Animal Kingdom.
20. S. Carl Hirsch. Living Community.
21. Ross Hutchins. Strange Plants and their Ways.
22. Hans Hwass. Reptiles of the World.
23. Margaret Hyde. Animal Clock and Compasses.
24. Margaret Hyde. Plants Today and Tomorrow.
25. Lucy Kawaler. Wonders of Algae.
26. Clarence Kylander. Flowers of Field and Forest.
27. R. D. Lawrence. Wild Life In Canada.
28. Vil Lanham. The Insects.
29. Life Nature Editors. The Mammals.
30. Marion Marcher. Monarch Butterfly (Winnipeg North and South)
31. George Mason. Animal Homes.

32. George Mason. Animal Tracks.

33. Charles May. Book of Canadian Animals.

34. Alfred Morgan. Aquarium Book for Boys and Girls.

35. Roy Pinney. Microzoa (Collecting and Photographing).

36. Rutherford Platt. Great American Forests.

37. Elsie Proctor. Looking at Nature.

38. Ivan T. Sanderson. Living Mammals of the World.

39. Millicent Selsam. Courtship of Animals.

40. T. Dewey Soper. Mammals of Alberta.

41. SuZan, Swain. Insects In Their World.

42. Stuart Thompson. 80 Water Birds and Birds of Prey.

43. Robert Usinger. Rivers and Streams.

44. T. L. Van Camp. Fifty Trees of Canada.

45. Frits Went and Life Nature Library. The Plants.

46. Alexander Wetmore. Song and Garden Birds of North America.

47. Eric Roberts. Animal Ways and Means.

D. Audio Visual Material

Films (Edmonton Public School Board)

F 649 The Community
F 746 Plant and Animal Communities
Ecological Succession

F 771 Succession - From Sand Dune to Forest
F 790 What is Ecology?

8 mm film loops

Fl 423 Collecting Edge Community Organisms
Fl 481 Recognizing Edge Community Organisms

INVESTIGATION I

Objectives for the Laboratory:

a. To acquaint the student with a part of the biosphere that he lives in, in hope that he will better understand the value of this biosphere.

b. To illustrate or show some of the relationships that the student has been told exists in all ecosystems and that exists in particular in a pond ecosystem. (eg. predation, competition, succession, etc.).

c. To acquaint the student with some of the organisms that are common to Alberta.

General Comments

1. In this field trip students should be organized so that they are working in groups of two, three or four, depending on what data they are collecting. It is suggested that the following numbers of students be placed in each group.

group one	abiotic data	2 students
group two	mud samples	3 students
group three	aquatic animals	9 students (3 groups of 3)
group four	aquatic plants	3 students
group five	terrestrial plants	6 students (2 groups of 3)
group six	terrestrial animals	3 students
group seven	water collectors	2 students

2. This laboratory investigation is based on the use of a pond ecosystem. We realize that getting to and from such places and organizing such trips does present some difficulties. Of the five major types of ecosystems that can be investigated, the pond offers more variety of organisms than any of the others. Thus the possibility of finding some of the relationships that have been discussed in class are much greater. For this reason it is felt the pond ecosystem is probably the best to use of the five possibilities. As far as the difficulty of getting to the pond goes, it is hoped that this will be overcome by the teacher. Students in grade seven are usually extremely willing to pay a dollar or two to pay for the buses to get out to the pond. As far as time goes, Saturday field trips can be made without any trouble at all.

If a field trip is impossible to arrange, the teacher may attempt to use some of the films and film loops listed at the end of this unit. This of course does have many drawbacks, but if necessary it can be done.

Design for Data Collection

Student's notes pages 2 and 3.

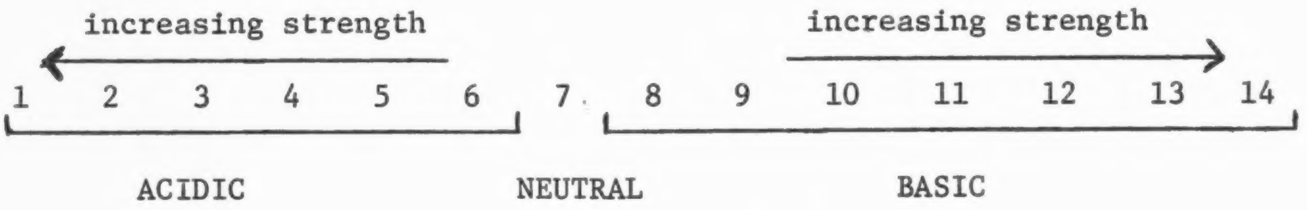
1. One thing should be pointed out to the students and impressed upon their minds from the start. This field trip is for scientific purposes. It is not a "fun time" trip. If the trip is structured well enough this should be accomplished.

2. It is, as is pointed out in the design, a good idea to visit the pond prior to your class trip. A sketch of the area should be made and the places where sampling can be done, should be indicated on this map. This may help prevent students from running all over the study area taking meaningless samples.

Student's notes page 4.

1. Most of the data collected here will have very little meaning to the student in terms of observable relationships with the organisms in the pond. If a study of a second pond was done and if this second pond was such that the abiotic data from it was completely opposite to the original study, then the student would see the effects that temperature, pH, wind, oxygen content, etc., have upon the organisms in the pond. However, this is not the case. It is hoped that some relationships will be seen between the abiotic and biotic elements in the pond. At best they will come to realize these elements.

2. It will be necessary in a pre-laboratory period to explain the meaning of the term pH. This is a concept that is fairly easy for grade sevens to learn, since they are already familiar with acids. It is suggested that a line diagram, such as the one below, be used for this purpose.



Student's page 5.

1g. Six mud samples are taken by this group. Two of these samples will be analysed for organisms that dwell in the mud. The remaining four samples can be used later in the year or now. If they are to be used later, then place in a deep freeze. Be sure all or most of the water is out of them. Two things can be done with these samples in class regardless of whether you use them now or later in the year.

a. A study of population changes can be done by setting up artificial ponds in fish bowls. This is a difficult exercise for students to accomplish correctly but it is worth trying.

b. The mud sample, having been placed in fish bowls, could be used for pollution studies.

1h. The Berlesse Funnel method is illustrated in the appendix. If this equipment is not available a second simpler but less efficient method is given in the student's notes.

Student's notes pages 6 and 7.

This group (aquatic organisms) will be collecting organisms at the same location that is being used by the abiotic data group. The reason for this is to attempt to show some relationship between the abiotic and the biotic part of the environment. Most of the organisms collected could be identified to common names fairly easily by using books such as:

The Life of the Marsh
Niering, William A.
McGraw Hill, 1966
New York

The Life of the Pond
Amos, William H.
McGraw Hill, 1966
New York

Life Nature Library
Ecology
Time - Life

The keys supplied in the appendix will identify organisms to the order level but no further.

Group 4 is responsible for collecting aquatic plants. The keys for identification are not supplied and teachers must refer to the reference material listed earlier in the unit.

Student's notes page 8.

The main purpose of group five is to attempt to show succession around the pond. This could be pointed out to the whole class during the field trip. However, if the data collected is later used by the whole class and diagrams made in class using this data, they will remember better what succession involves.

Group five need not collect every type of plant found. Only those that are frequently found in each section are needed. This should be pointed out to them once they have begun to collect plants.

No key for plant identification is supplied. Refer to references listed earlier in unit.

Student's notes page 9.

The members of group six should be people who are fairly well acquainted with the birds and mammals found around Edmonton. Most of the identifying that they do will have to be done in the field with very little time for referring to books and keys.

The first 15 minutes or the last fifteen minutes of the trip should be used to allow students to make a full page diagram of the pond and the immediate area around the pond. Do not allow them to use their reference diagram for this purpose.

ECOLOGY: STUDENT'S NOTES

Problem

To identify the organisms that live in a pond ecosystem and to study the relationships that exist between these organisms and their environment.

Background Information

Define and write short notes about the following terms:

1. abiotic

2. biotic

3. primary consumer

4. secondary consumer

5. producer

6. community

7. population

8. habitat

9. succession

Design for Data Collection

In the investigation of a pond community a number of things must be sampled. These things that must be sampled or that data must be collected or can be divided into two groups; abiotic and biotic. In collecting this data it is essential that you cause a minimum amount of disturbance to the biosphere. All data must be collected in an orderly scientific manner. To accomplish this aim, a map has been drawn on the following page which illustrates the approximate points where each group will collect its data. As soon as you reach the study area consult your map so that you can locate your particular area for collecting. Every sample that is taken must be labelled. Each label should have the following information.

Specimen name:

Location:

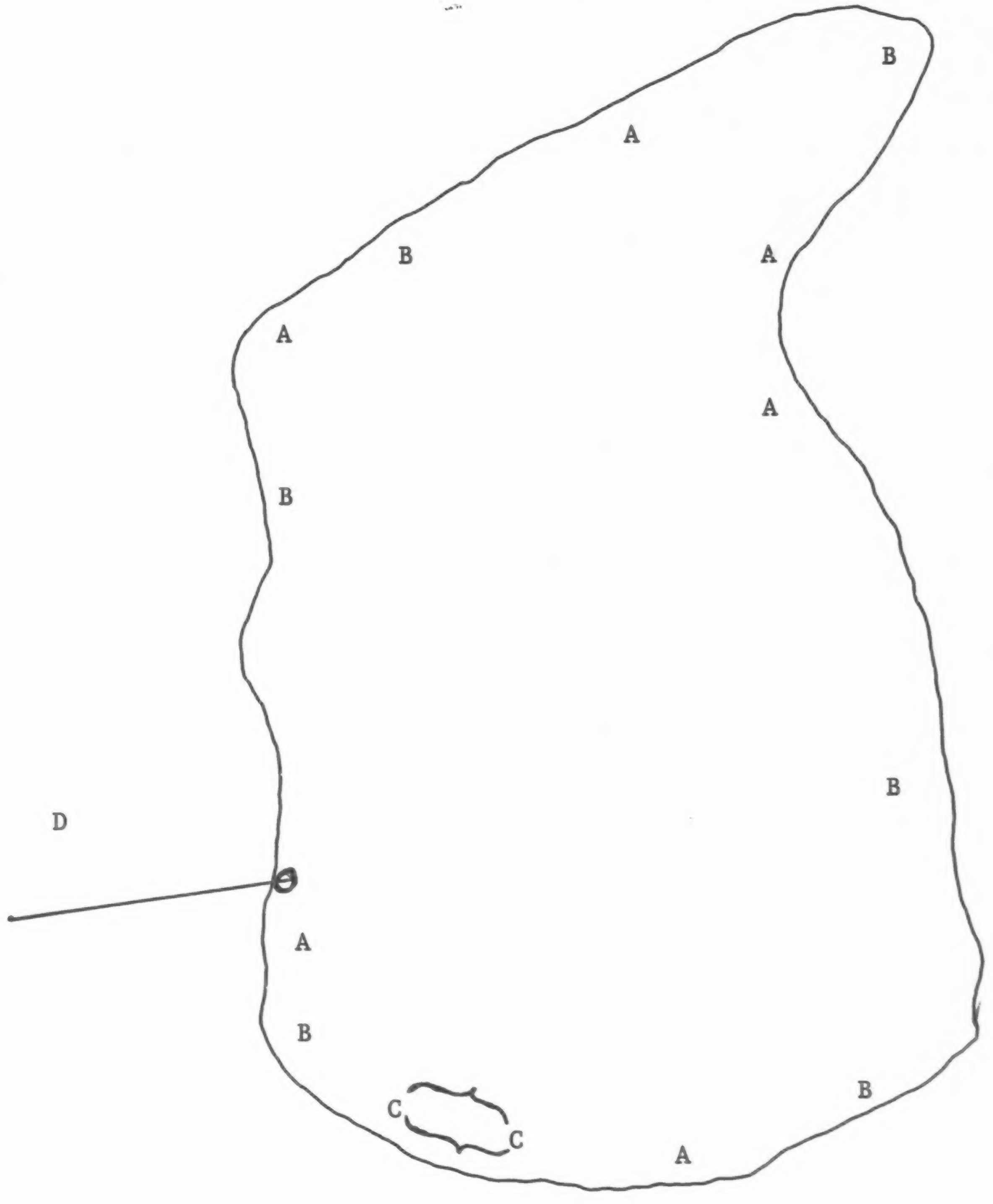
Miscellaneous Information:

Collector	Date Collected

These labels must be made before you go out in the field.

Each student, regardless of the group he is in, must read all the instructions given in the design.

POND SAMPLING GUIDE


B
A
B
A
A
A
B
D
B
A
B
C
C
B
A

Mud Samples	A
Aquatic Animals	B
Temperature Readings	B
Aquatic Plants	C
Terrestrial plants	D

I. Abiotic Data

1. Group one will be responsible for the collecting of abiotic data from the ecosystem. They will take their temperature readings at the same locations that is being used by the aquatic animals group. The temperatures must be taken first before any animals are collected. The temperatures of three areas must be taken and recorded at each of the five locations. These areas are, the air, the water, and the mud.

   a) Measure the temperature of the water at the edge of the pond. This should be done at a depth of about one to one and a half feet. Do this three times at each location. If possible, attempt to take temperature readings where the water is deeper (five or six feet deep). Be sure the thermometer is well below the surface of the water. (5 to 6 feet).

   b) Measure the temperature of the air just above the water surface of the pond; about two feet above. Do this three times at each of the six locations assigned to you.

   c) Finally measure the temperature of the mud below water level. Be sure the thermometer bulb is in the mud when you take your temperature readings. Do this three times at each of the six locations assigned to you.

   d) Obtain some phydrion (pH) paper from your instructor. Using this paper, determine the acidity of the pond water at each of the six locations. This is done by placing a one-inch strip of the paper in the water for about one minute. Remove the paper from the water and compare the paper to the color chart on the container that holds the phydrion paper. The color that most resembles the color of the paper will tell you the pH of the water. The pH is indicated by a number below the color chart (numbers from 1 to 14). If the number is six or below, the pond is acidic. If the number is eight or more the pond is basic.

   e) Obtain the following information for your general study area by phoning the Public Weather Office, at 299-7515. Be sure to tell them the area of Alberta that you want this information for.

      i) Relative Humidity
      ii) Barometric Pressure
      iii) Precipitation
      iv) Cloud Cover
      v) Wind Velocity
      vi) Wind Direction

II. Biotic Data

The remaining groups of students in the class will be responsible for the collecting of the biotic data. Each group will have a specific task to perform in the field and will at some later date give their data to the rest of the class. Each group will collect their organisms from a specific area of the pond. The diagram on page three illustrates these areas for you. All organisms collected (plant or animal) MUST be identified by the use of a key to at least the phylum level and further if the key permits.

1. Group two will be responsible for collecting and identifying organisms from mud samples taken from the pond. The members of this group should be equipped with the following items.

Equipment

1 pair of hip or chest waders
shovel
6 - 1 gallon jars or strong plastic bags

Method

a. Mud samples will be collected from the positions illustrated on the map.

b. Select a fairly shallow area near the position where you are supposed to take your sample. Using a spade or a small shovel, fill six - one gallon jars full of mud from the bottom of the pond. If you do not have jars, use very strong plastic bags.

c. Once the sample has been placed in the jar, drain as much water as possible out of the jar.

d. Label your jars with the appropriate information on the labels.

e. Be careful, don't wade into the water unnecessarily - you may fall.

f. Take six samples of mud from the positions shown on the map.

g. Upon returning to the school, do either one of the following two things, depending on what your instructor wants you to do.
   a) Drain as much water as possible from four of the mud samples. Place all four samples into a freezer and leave them for use later in the year.

OR

   b) Split four of the mud samples in half. Place each half into small fish bowls. Add water to the fish bowl until there is twice as much water as mud. USE POND WATER. Leave it sitting for a couple of days. Make sure each bowl is exposed to light.

h. The remaining mud samples will be analysed by either of two methods.

   (i) Berlesse Funnel Method

   (ii) Spread the mud sample out on a desk covered by newspaper. Using your fingers go through all of the mud that you have collected picking out all the organisms you find. Place each type of organism into a separate jar, and label the jars. Having done this identify these organisms using the keys in Appendix B.

2. Group number three will collect and identify aquatic orgnisms from the pond. Be sure to consult your map of the pond to determine what area you will take your samples from. When sampling animals from within the pond be careful not to disturb the water any more than is necessary.

Equipment

collecting jars
dip net
high rubber boots or hip waders

Method

a. Locate the area of the pond that has been assigned to you for your collecting. Do not start sampling until group one has finished taking temperature readings.

b. Samples should be taken from water that has a depth of approximately one to one-and-a-half feet.

c. When using the dip net be sure to draw it through the water with one continuous motion. (See Appendix A for the method used to construct a dip net.) At least three sweeps through the water should be made at each location.

d. Any organisms caught in the net should be transferred to collecting jars that contain pond water. Be careful when transferring these organisms to the jars that you DO NOT crush them. Make sure you get all of them off the net. Some of them are very small and can easily be missed.

e. Label all the jars and fill in as much information as possible on the label. (e.g. location organisms were found at).

f. Attempt to describe the type and amount of vegetation (none, partial cover, fully covered) at each location being used. Record this information on your label under miscellaneous information.

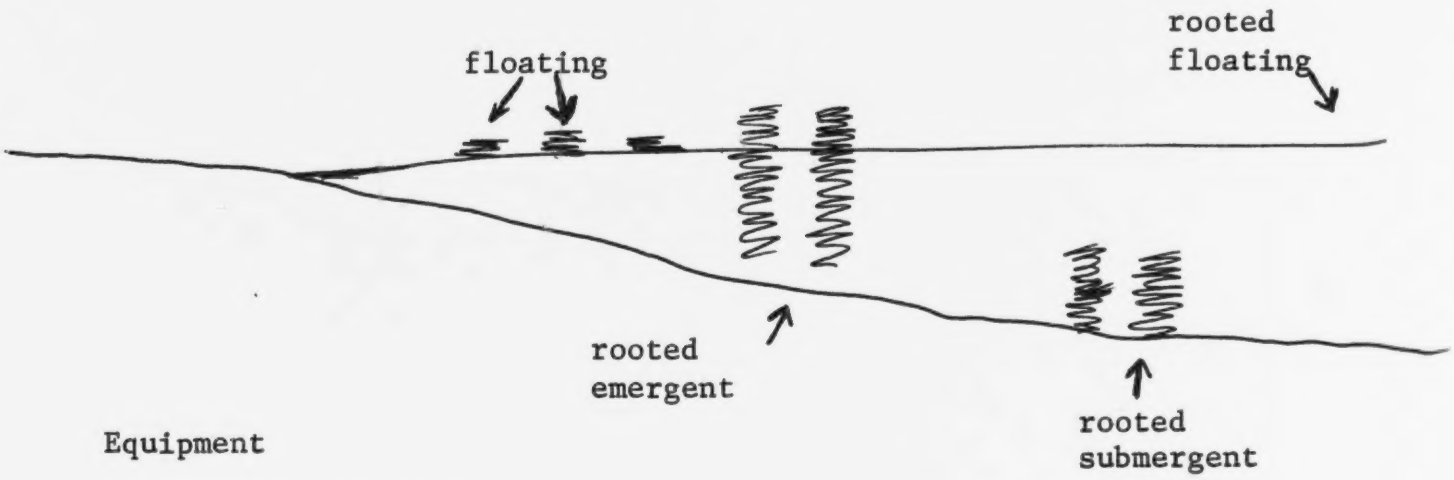
g. Attempt to place organisms of the same size in each jar. You don't want some organisms eating others.

h. This group should also collect any organisms they find on the surface of the water.

i. Once you have returned to the school remove all the lids from the jars so that oxygen can be supplied to these organisms.

j. In our remaining laboratory periods you will identify the organisms that you have collected. Do this by using the keys in Appendix B.

3. Group four is responsible for collecting plants for the pond. There are four zones from which plants can be collected. These are shown on the diagram below.



Equipment

collecting jars
small spade or shovel
labels
hip waders

Method

a. Consult your map to locate your collecting area.

b. From each zone you should collect one plant of every type found in that zone.

c. If the plant is a rooted plant collect its roots as well as the stem.

d. When you place these plants in the collecting jar be sure to include water and some mud from the pond.

e. Label each jar as to the zone from which the plant was located. Also record on the label the number of plants of the same type that are approximately the same location.

f. Once you have returned to the school remove all caps from the jars.

g. In the following laboratory periods identify each of the plants found.

h. After you have identified them you will press and mount them. Instructors for this are given in Appendix A.

4. Group five will be responsible for the collecting of data from the terrestrial zone around the pond. This is the fifth zone of plant growth. (Group three sampled zones 1, 2, 3, and 4).

Equipment

50 - 2 ft. long strings
4 - 12 inch stakes
200 feet of string
100 foot tape measure

Method

a. Consult your map to locate your section of the study area.

b. Once you have located your study area, place one of the two stakes you have in the ground at the water's edge.

c. Attach the string to this stake.

d. Extend the string out from the pond for a distance of 100 feet.

e. At this point place your second stake and attach the string to it.

f. Do exactly the same thing again with the remaining two stakes and the 100 feet of string. This second line should be placed exactly two feet away from the first line so that they are running parallel to each other.

g. Next, mark off each of the lines in two foot sections. Do this by measuring two feet from the stake. At this point attach a string which will go across from one line to the next. Continue doing this along the 100 foot line. When you have finished you should have what looks like a rope ladder.

h. Begin taking your sample in section one of the ladder (section closest to the water. The section farthest from the H_2O will be section number fifty.

i. Collect one plant of each type found in each section. Estimate the area (in percent) that each type of plant occupies in each square.

j. Place each type of plant in a collecting jar and label it as specimen A, B, C, etc. On each label, under miscellaneous information, write in the percentage area that that specimen occupies in the section. Also write down which section the specimen was taken from.

k. When collecting these plants be sure to include as much of the root as possible.

l. If the plant is too large to collect as a whole plant (i.e. trees, shrubs) then collect one or two leaves of the plant instead.

m. Upon returning to the school, use your remaining laboratory periods to identify each plant (using available references) and to press and mount them (as described in Appendix A), after they have been identified.

5. Group six will have the responsibility of identifying and counting any of the larger type organisms, such as field mice and birds. The members of this group should be fairly familiar with the names of birds found in Alberta. They will record the name of the animal found or sighted and the number of different ones of the same types they see.

Eg.

ANIMAL	NO. SEEN
Mallard duck	5
Red wing black bird	10

The collection of this data should be made in the immediate vicinity of the pond. The following books may help in the identification of these organisms.

Mammals of Alberta
Birds of Alberta

6. Two students should be assigned the task of collecting pond water in large sealed containers. This water will be used in the laboratory to attempt to set up a balanced fresh water aquarium, using the organisms that have been collected by other groups.

7. All students must make an accurate diagram of the pond that is being studied. This diagram must be in proper proportion and must illustrate the landscape surrounding the pond. (location of roads, trees, shrubs, etc.).

OBSERVATIONS

I. Abiotic Data

1. Water Temperatures (depth = 1' - 1½')

Temperature Reading	Station Number					
	1	2	3	4	5	6
1						
2						
3						
Average						

Water Temperatures (depth = 5' - 6')

Temperature Reading	Station Number					
	1	2	3	4	5	6
1						
2						
3						
Average						

2. Air Temperatures

Temperature Reading	Station Number					
	1	2	3	4	5	6
1						
2						
3						
Average						

3. Mud Temperatures

Temperature Reading	Station Number					
	1	2	3	4	5	6
1						
2						
3						
Average						

4. pH of Water

pH	STATION NUMBER					
	1	2	3	4	5	6

5. Miscellaneous Information

Relative Humidity ______________________

Barometric Pressure ______________________

Precipitation ______________________

Cloud Cover ______________________

Wind Direction ______________________

Wind Velocity ______________________

II. Biotic Data

1. Mud Sampling

NAME OF ORGANISM	NUMBER FOUND

2. Aquatic Animals

NAME OF ORGANISM	NUMBER FOUND	AMOUNT OF VEGETATION*	CONSUMER LEVEL

* partially covered, fully covered or none.

3. Aquatic Plants

NAME OF PLANTS	ZONE FOUND IN*	NUMBERS OF SIMILAR TYPES FOUND IN THE AREA

* zones = rooted emergent
rooted submergent
rooted floating
floating

4. Terrestrial Plants

Table 1

SECTION NUMBER	NAME OF PLANT	PERCENTAGE IN THE SECTION

4. Terrestrial Plants

Table 2

NAME OF PLANT	TOTAL PERCENTAGE OCCUPIED (in 100 feet)

5. Terrestrial Animals

NAME	NUMBER SEEN	APPROXIMATE LOCATION	CONSUMER LEVEL

Organization of Data

In the table below list the ten producers found most frequently in the pond. Do the same for the primary consumers (top 5) and the secondary consumers (as many as you can find).

Producer	Primary Consumer	Secondary Consumer

Interpretation of Data

1. From the data in your observations, construct a food web.

2. Discuss what would happen to one of the organisms in the second level, if your food web all died.

3. Were any of the following relationships existent within the pond? If so, discuss:

   mutualism

   commensalism

   parasitism

   predation

   competition

4. Referring to your observations on terrestrial plants, draw a one page diagram which illustrates the plants involved in succession at this pond. (Refer to pg. 40 of Exploring Life Science).

5. Is there any relationship between the pH of the water at various places in the pond and the type of species of animals at those locations? That is, are any animals specific to a certain pH?

6. Is there any relationship between the temperature of the water at various places in the pond and the type or species of animals found in that location?

7. Is there any relationship between the type of animal (species) found and the amount of vegetation found in the pond? That is, do certain animals prefer lots of vegetation; no vegetation; or a little vegetation. If there are, which ones prefer what amount of vegetation?

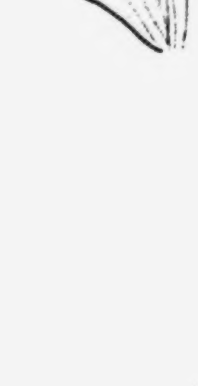
8. Do certain animals prefer to live in areas where only certain types (species) of plants are found?

FIELD
STUDY
GUIDE

GRADE SEVEN

D. S. MacKENZIE JUNIOR HIGH

R. W. PHARE & M. BODNAR



INTRODUCTION

Many of the concepts we talk about in life science, and many of the things we look at are isolated from their natural surroundings. A field trip allows us to see plants and animals in their natural habitat.

A pond, lake, or stream will afford many opportunities for worthwhile discoveries.

In the spring and summer a pond is a constant area of activity. Water insects shoot across the surface. Scavenger Beetles may be seen searching for their food just below the surface. If one looks extremely close one might see a frog or salamander darting among the weeds below.

As the seasons progress and autumn approcaches, the water cools and the activity is more quiet. However, a keen observer can see much.

In the winter the ponds, lakes, and streams freeze over and very little activity is noticed.

During the course of the term we will examine life in the ponds, lakes, and streams around Edmonton, so that we might gain some understanding of how life changes through the seasons.

R. W. Phare

M. A. Bodnar

STUDENT CONDUCT WHILE ON A FIELD TRIP

When going on a field trip we are still under the jurisdiction of the Edmonton Public School Board.

Students will be expected to conduct themselves in a manner befitting young ladies and gentlemen.

While in the field, where there are numerous activities going on at once, it is necessary that you listen for instructions and follow them.

We will use a "buddy system" to make it easier to keep together. This will be explained in class.

This will be the first of a series of field trips we hope to take during the term. Its success will depend upon you.

Dress for a Field Trip

1. Rubber boots or other suitable footwear.
2. Girls will wear slacks.
3. Gloves
4. Jacket

EQUIPMENT LIST

Many of the living things we will see can be observed and identified in their natural surroundings. However, it may be necessary to collect them for closer observation in the laboratory. Below is a list of equipment we will use for our observations and collections.

* 1. Aquatic net

* 2. Aquatic sieve (we will make this in class)

* 3. 6 - 10 large plastic (bread) bags.

* 4. 10 - 20 labels (2" x 1")

5. Jacknife or hunting knife in a sheath (1 per pair)

* 6. 3 or 4 pill bottles, with lids (if you can get them)

* 7. 3 or 4 jars (12 oz.) with tightfitting lids.

8. Waterscope

* 9. A carrying bag (a packsack or cloth sack is best)

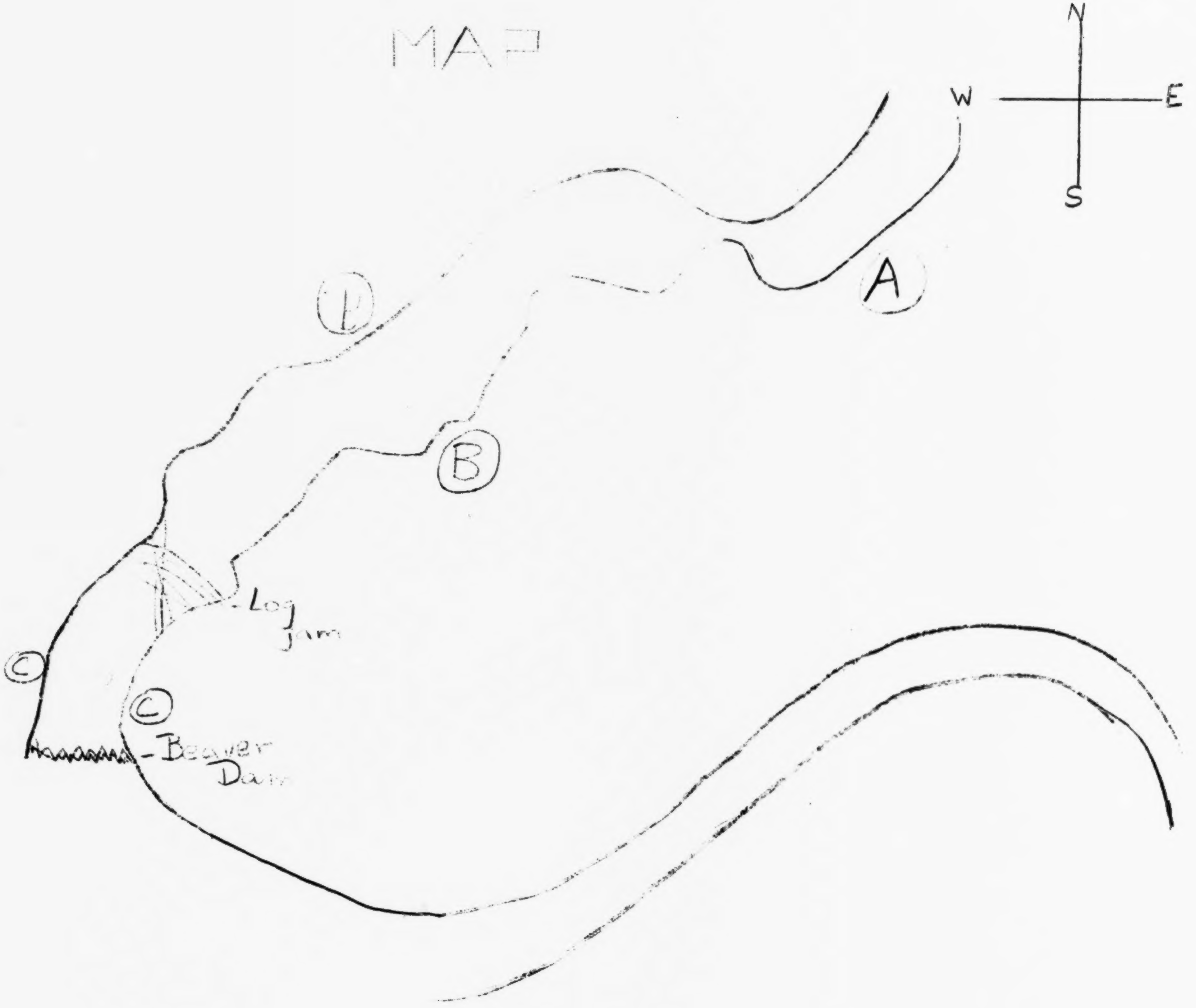
NOTE: Students will be expected to have as much of the equipment, marked with a star, as possible.

RESEARCH AREA

The field trip will take place at a site approximately 1 mile west of the school in a ravine. We will confine ourselves to the ravine area, and will study the flora and fauna (plant and animal life) here.

Study the map on the following page. This will be used during the course of your study.

MAP


N
W
E
S
A
D
B
Log jam
C
C
Beaver Dam

PROCEDURE FOR OBSERVING AND COLLECTING

Each pair of students will carry out ALL of the following activities. You will record your observations in written or diagram form in the space provided. ALL specimens are to be labelled.

ACTIVITY 1

1. Your observations will be made on the north side of the stream.
2. Note the plant and animal life on the north side of the creek, beginning at the water's edge and working up about 30 yards.
3. Describe what you see (compare animal and plant life, their sizes and kinds).

Record of Observations: (include written descriptions and diagrams.)

ACTIVITY 2

1. Your observations will be made on the south side of the pond.

2. Note the plant and animal life on the south side of the creek, beginning at the water edge and working up about 20 yards

3. Record your observations on the plant and animal life (compare their sizes and kinds).

Record of Observations:

ACTIVITY 3

1. This activity can be carried out anywhere in the research area.

2. Collect leaves and small stem samples from 6 different plants in the area. Put each in a separate plastic bag and label each bag. Number each sample you collect and place the number on the map indicating the area from which the sample was taken.

NOTE: You will have to make and record observations on the whole plant if it is not possible to collect the whole plant.

Record of Observations:

ACTIVITY 4

1. This activity may be carried out anywhere in the research area.

2. Make observations of animal life and record them, in the space below as well as on the map.

3. When possible collect what living material you can. Label and number all specimens. Place the specimen number at the correct location on the map.

Record of Observations:

ACTIVITY 5

1. This activity will be carried out at the creek at points A, B, and C on the map. DO NOT GO IN THE WATER.

2. You will be asked to take samples of water from the creek at each point as follows:

   a. Take a sample of creek water from the surface, near the bank.
   b. Take a sample of water about 6" to 12" below the surface of the water.
   c. Take a mud sample from the bottom of the creek bed.

3. LABEL EACH SAMPLE

Record of Observations:

A GUIDE TO COLLECTING AND CULTURING
LOCALLY OBTAINABLE FRESHWATER ORGANISMS
IN THE EDMONTON AREA

by

Kenneth G. Jacknicke

February, 1968

LIMITATIONS

Because of the wide variety of organisms which it is possible to collect for use in the science class, it is felt necessary to restrict the paper to one area. The main area to be considered will be the fresh-water environment and the organisms which can be found in that type of habitat. Specifically, lakes, ponds, sloughs, creeks, and water-filled ditches will be considered.

ORGANISMS TO BE FOUND

The waters around us abound in interesting organisms quite suitable for biology laboratory work and special projects. Many organisms can be found in ponds, temporary puddles, springs, streams, lakes and almost any other location that holds water for any length of time. The organisms found reflect environmental differences in salanity, p^H, temperature, light, water movement, and oxygen content. The students will be astonished at the different shapes, brilliance of color, and the elaborate appendages found on many of the specimens. Identification of many species is difficult requiring detailed study of the morphological characteristics on which classification is based. However, classifying the organisms into large groups is not too difficult. When attempting to separate species students will gain insight into the dynamic process of evolution in living organisms by noting similarity in form between species and individual differences within species. Students can also gain insight into the difficulties of taxonomic subjectivity and can see why some biologists are "lumpers" while others are "splitters" (Sherman, 1962).

The following organisms are some of the more common animals to be found in a variety of fresh-water habitats.

Stone-Fly Larvae

This organism is usually found in flowing water. It has gills on the ventral surface and two abdominal cerci (appendages at the end of the abdomen). The larva stage lasts from one to three years, depending upon the species.

May-Fly Larvae

These organisms usually have tracheal gills and three cerci. The larva stage lasts about one year.

Damsel-Fly Larvae

They have long, thin bodies and three caudal fins which are feathery in appearance. They swim by serpentine movements of the body. The larvae stage lasts up to five years, but is usually about three years duration.

Dragon-Fly Larvae

Possess a short, stout body with an absence of external gills. They swim by shooting ahead rapidly through the water. The larva stage lasts about three years.

Caddis-Fly Larvae

These organisms possess a case which they never voluntarily leave. The case may be constructed of many types of foreign material, such as stones, grass, leaves, snail shells, and functions to protect the soft abdomen. They are primarily vegetarian.

Phantom Midge

Both larva and the pupa stages of the adult mosquito can be found, especially during the spring and early summer.

Fairy Shrimp

These animals are found only during early spring up to about the first of June. They swim on their backs using graceful strokes of their abdominal appendages. They are primarily vegetarian.

Freshwater Shrimp

These animals are commonly found under stones on the bottom. They are active vegetarians.

Copepods

These are very small filter feeders. They can be identified by the very jerky motion while they are swimming, e.g., *Diaptomus sp*., *Cyclops sp*.

Ostracods

Organisms which possess a double-valved shell and usually lives on the bottom. They can be identified by the very smooth motion while swimming.

Cladocerans

Organisms usually larger than Copepods but swim with a similar jerky motion.

Aquatic Beetles

There is a large variety of organisms which can be placed in this category. Both adult and larva forms are quite common, e.g., water boatman, backswimmer, diving beetle, whirlygig.

Water Mites

A common rather small predator which belongs to the same class as the spiders. They swim very rapidly and very smoothly.

Snails

These animals abound in many types of water and there is a large variety of species.

Tubifex

These are small white worms which live in mud cases on the bottom of ponds, sloughs, and lakes. They are very common.

Leeches

There are several genera to be found. They are very common and easily obtained.

Planaria

There are two very common types in Alberta. They are usually found on rocks or vegetation on or near the bottom. They are flat and worm-like in appearance.

Hydra

These organisms are abundant in some areas. They are small sedentary animals and feed on crustaceans.

Frogs

These are plentiful and are found in almost any area where they can obtain moisture.

AREAS INVESTIGATED

It has been found by a rather wide but superficial study of aquatic environments in the Province of Alberta, that many freshwater organisms are common throughout the Province. Specifically, in the Edmonton area, five locations will be discussed. Each location is an example of a typical type of environment and there is no doubt that many of the organisms mentioned can be found in many other locations in the Edmonton area.

Bremner

A water-filled ditch located about two miles east of Edmonton which was examined May 9, 1967. In this ditch were found fairy shrimp, caddis fly larvae, mosquito larvae, cladocerans, ostracods, may-fly larvae, frogs, phantom midge larvae, copepods, water beetles and snails.

Ellerslie

A pond located two miles east of Ellerslie corner. In this pond, visited several times in October, 1967, were found cladocerans, gammarus, ostracods, copepods, damsel-fly larvae, phantom midge larvae, snails, stone-fly larvae, Dytiscus sp. (water beetle) larvae, and tubifex.

Nisku

A slough located nine miles south of Edmonton on Highway 2 and visited July 5 and several times during the month of October, 1967. During these investigations were found cladocerans, planarians, frogs, water beetles, copepods, ostracods, snails, caddis fly larvae, and tubifex

Wabamun Lake

The lake is located fifty miles west of Edmonton. There is an outlet on the edge of the lake. Water which enters the canal from the power plant keeps the canal at a temperature of about ten degrees Centigrade during the mid-winter months. Because of this, the location is an excellent source from which one can secure live materials during the months when most other areas are frozen over. From this area one can obtain Hydra, Planaria, copepods, cladocerans, ostracods, leeches, freshwater clams, snails, stone-fly larvae, damsel-fly larvae, tubifex, and various species of fish.

White Mud and Black Mud Creeks

These creeks are located two miles south of Edmonton. Visited several times during October, 1967, both creeks supplied a number of dragon-fly larvae, damsel-fly larvae, caddis fly larvae, leeches, a minimal number of crustaceans, small fish, freshwater clams and tubifex.

EQUIPMENT NECESSARY AND METHOD OF COLLECTING

The equipment necessary for collecting is extremely simple. Much of the collecting may be carried out by means of a simple dip net constructed out of a coat hanger and a nylon stocking. The hanger is straightened out and a loop is constructed at one end which should be approximately six inches in diameter. The nylon is then stretched tight over the loop and is sewn on. Because the mesh of the nylon is very fine, many very small organisms can be caught in the net. If the nylon is stretched tight so that a funnel-shaped net does not result, the small organisms, such as fish, are to be caught. The remaining equipment consists of a number of jars in which to keep the specimens, thirty-two ounce or sixteen ounce will suffice, and a dip net which can be purchased from a biological supply house. However, the purchased net is necessary for only a small number of organisms.

When obtaining a sample, the nylon net should be drawn through the water with a continuous motion. Organisms caught in the net should be transferred to a jar containing water from which the sample was taken. To remove the organisms easily from the net, the jar should be filled to the brim with water. The net containing the trapped organisms can then be inverted over the mouth of the jar. By pressing the nylon into the water in the jar, the organisms are able to swim off the net into the container relatively unharmed. A small amount of green aquatic vegetation should be added to the jar to supply oxygen for the trapped organisms. Care should be taken to keep carniverous forms separate from herbiverous ones. The jars can then be capped for transportation but should be opened immediately upon arriving at their destination.

The coat hanger net is usually sturdy enough to do some light probing in the debris and mud on the bottom of the pond or other area being investigated. However, to do extensive bottom sampling the purchased dip net should be used. One difficulty in using this type of dip net is that the mesh is often too large to hold any small organisms, such as crustaceans.

During the investigation of an aquatic environment, it is often wise to obtain a number of mud samples from the area. A mud sample may be obtained from the water's edge, or from the dry bottom of a temporary body of water. These samples should be coded as to date and location and may be stored in four ounce jars for study at a later time. It is often a good idea to leave the container open until the mud sample is completely dehydrated. These mud samples may be used to start cultures of organisms six or seven months later.

MAINTAINING CULTURES

The best culture methods for maintaining living organisms are those that reproduce the most favorable environment and eliminate natural enemies (Brandwein, 1966). To help do this there are a few general conditions that should be kept in mind whenever an attempt is being made to culture living organisms.

1. Keep the culture at a constant temperature within 18-21 degrees Centigrade.
2. Keep the culture away from the fumes of volatile substances.
3. Keep the cultures approximately neutral (p^H of 7.0).
4. Keep the cultures in medium light.
5. Avoid drafts which can cause temperature fluctuations or carry airborne contaminations.
6. Keep the glassware clean at all times (Brandwein, 1966).

FRESH CULTURES

Protozoans

The apparent simplicity of these organisms lend them readily to the study of feeding, taxes, reproduction, growth and other biological phenomena. Brandwein (1966) lists several methods by which amoeba can be cultured. One easy and simple method is to establish a hay infusion. Place dead hay or grass (even wilted lettuce will do) in a jar and add pond water. If pond water is not available, distilled water or aged tap water which has stood in an open container for at least forty-eight hours will suffice. Within two weeks, the jar will usually contain a large variety of protozoans. If a pure culture is desired, the pond water and hay may be boiled for approximately ten minutes to destroy any organisms. After cooling, the desired organism may then be innoculated into the culture.

Hydra

This is an excellent organism to illustrate concepts of ingestion, regeneration, sexual differentiation, taxes, rate of growth, and differentiation on the tissue level. After the organism have been collected, they should be left in the jar containing water that they were found in. When adding new water, do so slowly over an extended period of time to acclimate the organisms. The cultures should be kept in medium light at a temperature not exceeding twenty degrees Centigrade. The Hydra should be fed twice a week on a rich culture of crustaceans.

Planaria

Flatworms are excellent for illustrating regeneration and taxes. Occasionally, black cocoons may be found in the culture. On June 9, five planarians were obtained from the Wizard Lake south of Edmonton and were kept in a large finger bowl. They were fed raw liver once a week. During this confinement, they laid eight cocoons by June 28, 1967. By July 12, two of the egg cases had hatched out young planarians which were miniature adults. Planarians have been kept as long as three and four months in jars without any special care except an occasional feeding. However, care must be taken to remove any excess food from the culture as this will foul the water. An occasional feeding of hard-boiled egg yolk will also maintain the culture.

Tubifex

This is an easily maintained aquatic worm. Once collected, they can be introduced to an established aquarium with a muddy bottom. If desired, they may be maintained in a jar containing mud and water from which they were taken. An occasional feeding of hard-boiled egg yolk ground up into a paste will keep them surviving for long periods of time.

Crustaceans

This group is composed of Cladocerans, Ostracods, and Copepods. They are very common and can be found inhabiting almost any body of water. They can be maintained with a minimum of difficulty. By placing them in jars containing pond water, distilled water, or aged tap water, and feeding them hard-boiled egg yolk paste, they can be maintained for long periods of time. A small amount of aquatic vegetation is desirable to supply oxygen for the organisms. Cultures of this type have been kept for as long as nine months. To make the paste, take a small amount of hard-boiled egg yolk, about the size of a small pea, and mix it with water from the culture. Add a small amount of this paste to the culture two or three times a week.

Gammarus

The freshwater shrimp can be maintained in a jar or an established aquarium. To feed, add a small piece of hard-boiled egg yolk every two weeks.

Fairy Shrimp

As of yet, no method has been devised for culturing these organisms with any great success. At most, a culture has been maintained for eight days.

Aquatic Insect Larvae

Mosquito and Midge larvae have been maintained in large finger bowls for several weeks. Feeding of hard-boiled egg yolk paste seems to work well. It may be found that the larvae will develop into the pupa stage and later emerge as adults while being kept in the culture. For this reason, it is often wise to keep the container loosely covered.

Other aquatic insect larvae have been maintained for varying lengths of time. Predaceous forms, such as Dragon-fly, Damsel-fly, and others, may be fed bits of raw meat or meal worm larvae. Vegetarian forms, such as Caddis fly, and May-fly larvae can be maintained in cultures containing green aquatic vegetation. The larger Stone-fly larvae are predaceous and will feed on a culture of crustaceans.

Water Beetles

These organisms may be maintained for periods of up to several weeks with a minimum amount of care. The predacous forms may be fed small bits of meat or other insects. The larvae of the diving beetle, Dytiscus sp., is a voracious carnivor and must be kept separate from other organisms. Mealworm larvae are an adequate food supply for these organisms.

Leeches

Leeches may be kept for extended periods of time, up to six months, without any specialized care. Simply keep the water fresh and add aquatic vegetation to supply oxygen.

Snails

Snails are easily cultured. All that is needed is a supply of aquatic vegetation to supply food and oxygen.

MUD SAMPLES

Mud samples are an excellent source of crustaceans and some other organisms during the winter months when it may be difficult to otherwise obtain them. The mud samples may be dried or frozen until needed. Samples which have been dried or frozen for periods of up to six months have shown a high degree of success when cultured. When a culture is desired, place the mud in a container, a thirty-two ounce jar will suffice, and add water. Care should be taken to use only small amounts of mud if it contains a large amount of organic material. If too much mud is used, the water will foul and there will be little chance of success. Out of seventy samples tried, thirty-five of tap water and thirty-five of distilled water, there was seventy-five percent success with distilled water versus eight percent success with tap water.

If the culture is a success, organisms will begin to appear in about two weeks. In this type of culture one can expect Cladocerans, Ostracods, and Copepods in abundance. Once in a while a culture will yield planarians, snails, and other types of organisms. If aquatic vegetation sprouts from the mud, and it usually does, a food supply is not often needed. If necessary, small amounts of hard-boiled egg yolk paste may be added to supplement the diet of the crustaceans.

UTILIZATION OF SPECIMENS

The following is a partial list of organisms which can be used to illustrate various biological concepts. If more information is desired on this topic, please refer to the list of references at the back of the paper. The organisms listed are the ones most commonly used, but many others would also serve a similar purpose.

Movement - almost any living organism previously mentioned.

Tissue Studies - Hydra

Ingestion - protozoans, Planaria, Hydra, aquatic larvae

Digestion - protozoans, larvae of Phantom midge, crustaceans.

Heartbeat - clams, cladocerans, snail embryo, Tubifex

Tropisms - light -- protozoans, Planaria, crustaceans
electricity - protozoans
chemicals - protozoans, Hydra, Planaria
contact - protozoans, almost any other invertebrate
gravity - Paramecium, snails, Planaria

Asexual Reproduction - protozoans, Hydra, Planarian

Sexual Reproduction - Paramecium, Hydra, snails, crustaceans

Regeneration - Hydra, Planaria, Tubifex

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APPENDIX [illegible]

LIFE

SCIENCE

A COLLECTION OF KEYS

COMPILED BY THE LIFE SCIENCE COMMITTEE

LIFE SCIENCE COMMITTEE

Bob Bruinsma	Vernon Barford
Don Hollands	Parkview
Rudy Melnychuk	Central Office
Al Merrick	Avalon
Lloyd Pearce	Strathearn
Wayne Phare	D. S. MacKenzie
Dave Powley	Steele Heights
Reg Roberts	Parkview
Ainsley Sankeralli	Ritchie
Henry Visscher	Vernon Barford
Norm Werenka	Avonmore

1970

KEY TO "WORM-LIKE ORGANISMS (Adapted from BSCS)

1A Body clearly segmented 2
1B Body unsegmented 5

2A Body of more than 15 segments 3
2B Body of 15 segments or fewer 9

3A Moderate to large worms 4
3B Small, slender worms; usually grey or white . . . .
. . . . Cl. OLIGOCHAETA (enchytraeids)
4A Usually pinkish or brownish; setae present . . . .
. . . . Cl. OLIGOCHAETA (earthworms)
4B Body rather flattened with sucker at each end; no setae . . . .
. . . . Cl. HIRUDINEA (leeches)

5A Small but not microscopic; tail undivided 6
5B Microscopic; tail divided into two 8

6A Body flattened; movements smooth and flowing . . . .
Cl. TURBELLARIA (flatworms)
6B Body slender and cylindrical 7

7A Body tapered toward ends; digestive tract complete . . . .
Cl. NEMATODA (roundworms)
7B Body uniformly cylindrical with bluntly rounded anterior end; degenerate digestive tract in adults . . . .
Cl. NEMOTOMORPHA (horsehair worms)

8A Cilia arranged in crown-like structure on head . . . .
. . . . Cl. Rotifera (rotifers)
8B Cilia on the body; body flattened, often bristly . . . .
Cl. GASTROTRICHA (gastrotrichs)

9A Abdomen soft and elongated, with fleshy false lets, different from jointed throacic legs 10
9B Abdomen without fleshy legs 11

10A Six or more pairs of false lets . . O. HYMENOPTERA (sawfly larvae)
10B Not more than five pairs of false legs . . . .
O. LEPIDOPTERA (moth larvae)

11A Body long, usually soft and grub-like; antennae usually very small . . . . O. COLEOPTERA (beetle larvae)
11B No jointed legs 12

12A Larvae usually elongate; head often small and indistinct. . . . .
. . . . O. DIPTERA (fly larvae)
12B Larvae relatively short and stout, often curved; with a distinct head 13

13A Head dark; body always curved . . .O. COLEOPTERA (weevil larvae)
13B Head light; body not always curved, rather inactive; usually colonial . . . .(larvae of bees, wasps, ants)

KEY TO THE COMMON ARTHROPODS

(Needham and Needham *A guide to the study of fresh water biology*)

1A Legs absent or represented by only short, unjointed projections . . 2
1B Legs present 3

2A Microscopic animals with eight stumpy legs . . . . O. TARDIGRADA (water bears)
2B Maggot-like animals of various sizes . . . . Cl. INSECTA 11

3A Numerous pairs or legs 4
3B Three or four pairs of legs 6

4A Most segments with two pairs of legs . . Cl. DIPLOPODA (millipedes)
4B One pair of legs per segment 5

5A Flattened bodies; prominent jaws; 15 or more pairs of legs when adult . . . . cl.CHILOPODA (centipedes)
5B Broad, arched thoracic segments with seven pairs of legs; narrower abdominal segments with smaller limbs underneath or behind . . . . Cl. CRUSTACEA (wood lice)

6A Head distinct from thorax; three pairs of legs; antennae usually present; wings may be present . . . . Cl. INSECTA
6B Head and thorax not separated; no antennae; four pairs of legs, occasionally only three in larvae . . . . Cl. ARACHNIDA 7

7A Large pedipalpi with pincers 8
7B Not as above 9

8A Abdomen of 12 ring-like segments with poison sting at end . . . . O. SCORPINONIDA (scorpions)
8B Abdomen of 11 segments, broader than the cephalothorax; no sting . . O. PSEUDOSCORPIONIDA (false scorpions)

9A Body clearly divided into two parts; spinning glands present . . . . O. ARANEAE (spiders)
9B Body not clearly divided into two parts; generally oval in shape; no spinning glands 10

10A Abdomen segmented; legs usually very long and slender . . . . O.PHALANGIDA (harvestmen)
10B Abdomen unsegmented; legs relatively short; small to microscopic in size . . . . O. ACARINA (mites)

11A Larvae usually elongate; head often small and indistinct . . . . O. DIPTERA (fly larvae)
11B Larvae relatively short and stout, often curved; with a distinct head 12

12A Head dark; body always curved . . . O. COLEOPTERA (weevil larvae)
12B Head light; body not always curved; rather inactive; usually colonial . . . . O. HYMENOPTERA (larvae of bees, wasps, ants)

KEY TO THE AMPHIBIANS OF ALBERTA

(Secondary Education Biological Sciences University of Alberta)

1A Tail present 2
1B Tail absent 3

2A Irregular greenish-yellow band or series of blotches along back; digits elongate, cylindrical, and without horny tips . . . . Ambystoma macrodactylum (Long Toed Salamander)
2B No band on back; body with greenish-white blotches on a dark network; digits short, broad, depressed, and with horny tips . . . . Ambystoma tigrinum (TIGER SALAMANDER)

3A Waist wide; body bread and thick; hind limbs short 4
3B Waist narrow; body relatively long and narrow; hind legs long . . . 7

4A Pupil of eye vertical; parotoids absent; black spade on hind foot; skin relatively smooth Scaphiopus bombifrons (PLAINS SPADEFOOT TOAD)
4B Pupil of eye horizontal or round; parotoids present; skin warty . . 5

5A Cranial crests present 6
5B Cranial crests absent . . . . Bufo boreas (WESTERN TOAD)

6A Cranial crests divergent at rear; raised horny boss extending from snout to just in front of eyes; parotoids small, widely separated and extending obliquely downward . . . Bufo cognatus . . . . (Great Plains Toad)
6B Cranial crests parallel; boss extending from snout to rear of eyes; parotoids large, less widely separated and not extending obliquely downward . . . . . Bufo woodhousei (WOODHOUSE'S TOAD)

7A Small discs on ends of digits; ventral surface granular . . . . Pseudacris nigrita (CHORUS FROG)
7B No discs on digits; ventral surface smooth 8

8A Red color on underparts; skin of back rough; dark spots with light centers on back . . . . Rana pretiosa (Spotted frog)
8B No red color on underparts; skin of back smooth; no light centers to spots on back 9

9A Dark spots with narrow light border; no dark patch behind eye . . . . Rana pipiens (LEOPARD FROG)

9B Dark spots without light border; dark patch behind eye with bar running forward to snout . . . . . . Rana sylvatica (WOOD FROG)

KEY TO THE REPTILES OF ALBERTA

Secondary Education Biological Sciences University of Alberta

1A Body snake-like 3
1B Body not snake-like 2

2A Body lizard-like; skin with numerous spines and tubercles . . . . . .
. . . . *Phrynosoma douglassi* (SHORT-HORNED LIZARD)
2B Body turtle-like with bony shell; underparts scarlet or yellow with black markings; longitudinal stripes on head, neck, and limbs . .
Chrysemys picta . . . .(WESTERN PAINTED TURTLE)

3A Rattle on end of tail; deep pit between eye and nostril . . . . . .
. . . . *Crotalus viridis* (WESTERN RATTLESNAKE) . . . .
3B No rattle on end of tail; no pit between eye and nostril 4

4A Snout pointed and upturned; wide black center band along yellow belly; very short tail . . . . . *Heterodon nasicus* (WESTERN HOGNOSE SNAKE)
4B Snout rounded and not protruding 5

5A Body unstriped; series of dark brown blotches along back; dorsal scales in 25 to 35 rows . . Pituophis catenifer . . . .
. . . . (Gopher Snake)
5B Body with longitudinal stripes; no blotches; dorsal scales in 19 to 21 rows 6

6A Lateral stripes on third and fourth rows of scales . . . .
. . . . *Thamnophis radix* (PLAINS GARTER SNAKE)
6B Lateral stripes on second and third rows of scales 7

7A Dorsal scales in 19 rows; seven supralabials; rear pair of chin shields considerably longer than front pair . . . .
. . . . *Thamnophis sirtalis* (COMMON GARTER SNAKE)
7B Dorsal scales in 21 rows; supralabials usually eight; both pairs of chin shields about equal in size . . . .
. . . . *Thamnophis elegans* (WESTERN GARTER SNAKE)

INSECT KEY I

Adapted from numerous sources - University of Alberta

You can identify some of the more common insects by using the key that begins on the following page. Its use depends on the elimination of all groups of insects except the group to which the particular insect belongs. The key consists of statements in pairs, or couplets. You start with the first couplet:

1a Wings and three pairs of jointed legs 19
1b No wings or wings too weak or too small to be used for flying 2

By looking at a certain insect and reading this couplet, you decide which of the statements describes the insect better. The number following this statement tells you which couplet to read next. You proceed by reading, observing, choosing, and following the numbers until you find a name instead of a number. Your insect belongs to the group named. In some cases, particular insects are given instead of a group name.

For example, if the particular insect has no wings, then statement 1b is correct. This statement refers you to couplet 2. Then you must decide if 2a or 2b describes the insect better.

2a Two or three long, threadlike projections at end of abdomen . . bristletail or silverfish
2b No such projections from abdomen 3

If 2a describes the insect, then the insect is a bristletail or a silverfish. If 2b describes the insect, then you must refer to couplet 3.

In the event that you are unable to decide which statement describes your insect better, then go on to the following couplet. Continue this procedure until you find a statement that describes some characteristic of your insect.

GENERALIZATION: AN INSECT KEY IS A USEFUL TOOL FOR INSECT IDENTIFICATION.

1a Wings and three pairs of jointed legs 19
1b No wings or wings too weak or too small to be used for flying 2

2a Two or three long, threadlike projections at end of abdomen . . . . . bristletail or silverfish
2b No such projections from abdomen 3

3a Legs or beginnings of legs 4
3b No legs 15

4a Legs which are used for locomotion 5
4b Legs which are not used for locomotion. (These are non-moving insects which are in the larva or pupa stage, or certain groups of insects which undergo a complete change in body structure and appearance during this stage, usually resembling adult forms.) 18

5a Head which is usally elongated, triangular, and bearing a cylindrical beak which contains piercing, threadlike mouth parts: the piercing-sucking type 6
5b Head which is usually more or less rounded, with jaws for chewing solid food rather than for sucking liquid food 7

6a Body flattened from side to side and bristled; hind legs fitted for leaping; body up to 3/16" long; parasitic on mammals and some birds . . . . SIPHONAPTERA -- flea
6b Body not flattened from side to side; body not hairy; up to 3/16" long; reddish brown; found in beds or in cracks in furniture. Sucks human blood . . . . Bedbug

7a Three pairs of legs on thorax and false, unjointed legs on abdomen; looks like a caterpillar . . LEPIDOPTERA - butterfly or moth larva
7b Legs on thorax only 8

8a Hind legs fitted for leaping; antennae as long as body or longer; drumlike ears on legs (exception: mole cricket has short antennae and digs with legs.) . . . . . . ORTHOPTERA -cricket
8b Hind legs (and other legs) fitted for running; all legs of about same strength and shape 9

9a Body shaped like a twig with legs; long, threadlike antennae . . . . ORTHOPTERA - WALKINGSTICK
9b Body not shaped like a twig with legs 10

10a Antennae as long as body or longer; body oval, depressed; head almost horizontal and either entirely or almost hidden from view by prothroax; hard and shiny looking; found in dark places where food is prepared or under loose bark of dead trees or logs . . . . ORTHOPTERA - cockroach
10b Antennae not as long as body 11

11a Head elongated to form a snout or beak with chewing mouth parts at the end of the beak . . . . . COLEOPTERA - snout beetle or weevil
11b Head and mouth parts not as described in 11a 12

12a Body caterpillar-like; three pairs of legs; head hard, free, and usually colored, with strong jaws . . . COLEOPTERA - beetle larva
12b Body not caterpillar-like 13

13a Huge mouth parts, biting claws; body is broad and somewhat flattened and tapers toward each end; found in small cone-shaped pits in sand; feeds on nats; up to ½" long . . . . NEUROPTERA - larva called ant lion
13b Without combination of huge biting jaws and flattened body 14

14a Thorax definitely separated from abdomen by a sharp, waistlike constriction, at which point there are one or two small knots or swellings . . . HYMENOPTERA - worker ant

14b Thorax not definitely separated from abdomen and without swellings; usually white or light in color; antlike in other respects; soldier caste has rectangular-shaped head which is hard and is equipped with huge jaws; insect never found in direct light . . . . ISOPTERA - termite of non-reproductive caste

15a Biting mouth parts 16

15b No biting mouth parts 17

16a Head is hard, free, and usually colored brown or black with strong jaws; found in soil or on plants. COLEOPTERA - larva of beetle

16b Similar to 16a but jaws are not as strong and body is paler in color and softer; found in or on other insects as parasites or in cell in a colony, but also may be found on plants . . . . HYMENOPTERA - larva of bee, wasp or ant

17a Breathing tube attached to last abdominal segment; abdomen very narrow; found just below surface of stagnant pond, with tube at surface . . . . DIPTERA - larva of mosquito

17b No breathing tube; body may be slender, short, or thick but usually conical, soft and white or light in color; mouth hooks in head but no jaws for biting; usually a conspicuous eyelike spiracle at the enlarged posterior end . DIPTERA - larva of fly

18a Legs and wings free from rest of body; body usually covered with envelope of silk or debris . HYMENOPTERA OR COLEOPTERA - pupa

18b Legs and wings not free from body, but attached at all points 39

19a Two wings plus tiny pair of knobbed, threadlike organs on the thorax just behind the wings . . . . DIPTERA - fly or mosquito

19b Four wings (2 pairs). Note: When front wings are horny and meet in straight line down middle of back or are thick and horny at base with membranous, overlapping tips, four wings may be assumed 20

20a Front wings membranous, i.e. flexible, thin, and more or less transparent, like cellophane 21

20b Front wings horny or leathery and opaque, i.e. hard like plastic or oilcloth 23

21a Front and hind wings alike in texture, i.e. same degree of thickness or transparency 27

21b Front and hind wings not alike in texture; front wings thicker and not quite so transparent as hind wings 22

22a First 2/3 or less of front wing (from point of attachment) thicker than rest of wing, which is membranous; these membranous tips overlap each other; head usually elongated and triangular, and bearing a cylindrical beak that contains piercing, sucking mouth parts and arises from front area of head . . . . HEMIPTERA - true bug

22b Front wings same thickness throughout and usually held rooflike over back; piercing, sucking mouth parts arising from rear area of head . . HOMOPTERA - scale bugs, aphid, cicada, leafhopper

23a Front wings horny and opaque, and meeting lengthwise down middle of back; body hard 24
23b Front wings more or less leathery, somewaht opaque; body softer. . . 25

24a Pincer or forcep-like appendage on tip of abdomen . DERMAPTERA - earwig
24b No pincer on abdomen . . . . COLEOPTERA - beetle

25a Hind legs fitted for leaping; mouth parts fitted for chewing solid food, i.e. on head which is usually more or less rounded, with jaws for chewing; front wings leathery, hind wings folded like plaited fan . . ORTHOPTERA - grasshopper
25b Hindlegs not fitted for leaping - all legs about the same size and shape 26

26a Body long and pencil-shaped; fore legs modified for grasping and holding its prey . . . . ORTHOPTERA - praying mantis
26b Body flattened and oval; head almost horizontal and entirely or almost hidden from view by prothorax; hard and shiny looking with antennae as long as body or even longer. ORTHOPTERA - cockroach

27a Wings opaque because of covering of minute, flat, shinglelike scales that appear powdery when rubbed off 28
27b Transparent wings 30

28a Antennae featherlike or threadlike; wings held horizontally at rest or folded around body . . . . LEPIDOPTERA - moth
28b Antennae not featherlike or threadlike; enlarged at tip to form a club or hook 29

29a Tip of antennae recurved. . . . . LEPIDOPTERA - skipper
29b Tip not recurved . . . . LEPIDOPTERA - butterfly

30a Wings long and narrow with only one or two longitudinal veins; both edges of wings fringed with hairlike bristles; body less than 1/8" long . . . . . THYSANOPTERA - thrip
30b Wings not fringed; mostly larger insects 31

31a Wings net-veined-- like fish net or hair net; many longitudinal and cross veins which intersect in netlike fashion 32
31b Wings with few longitudinal veins and few or no cross veins 36

32a Front wings larger than hind wings 33
32b Hind wings larger or equal to front wings 35

33a Antennae long and very conspicuous and greatly segmented; head prolonged downward to form a beak with chewing parts at tip; abdomen long and slender; wings long and narrow . . . . MECOPTERA - scorpion fly
33b Antennae short and not conspicuous 34

34a Wings triangular in shape; body ending in two or three long, slender antennae-like appendages called cerci . . . . EPHEMERIDA - mayfly
34b Wings not triangular in shape; no cerci on abdomen; strong flyer . . . . ODONATA - dragonfly

35a Wings held rooflike over back when at rest, lacy pattern of veins; cerci when visible are antennae-like . . . . NEUROPTERA - lacewing
35b Wings lie flat on abdomen when at rest; body usually ending in two or three long cerci . . . . . PLECOPTERA - stone fly

36a Wings held rooflike over back at rest 38
36b Wings lie flat on abdomen when at rest 37

37a Wings equal in size, shape, texture, and veins; wings long extending beyond abdomen when at rest; wings lie flat on back; antlike in appearance; separation of thorax and abdomen not distinct . . . . ISOPTERA - termite of productive caste
37b Wings not equal in size, shape, or veins; with the exception of sawfly, the abdomen and thorax are clearly separated by a constriction which forms a thin waist; female usually has a visible stinger (spearlike egg-laying organ); front and hind wings connected by minute hooks . . . HYMENOPTERA - wasp (See also couplet 40)

38a Hind wings almost as large as front wings; may appear to have hairy wings in some species . . . . TRICHOPTERA - caddis fly
38b Hind wings much smaller than front wings; never hairy; seen on leaves of trees and on fences . . . CORRODENTIA - psocid

39a Body encased in cover of silk (cocoon) . . LEPIDOPTERA - pupa
39b Body encased in brown, oval segmented case or puparium . . . . .DIPTERA - pupa

40a Waist with one or two small knots or swellings . . . . .HYMENOPTERA - reproductive ant forms
40b Waist without small knots; usually a stinger or "saw" on abdomen of female .. . . HYMENOPTERA - bee wasp

KEY TO THE ORDERS OF COMMON ADULT INSECTS - II
(Adapted from BSCS)

1A Wings absent 2
1B Wings present 16

2A "Spring" present on fourth abdominal segment, held by a catch on the ventral side; antennae shorter than body and usually bent like an elbow near the middle . . . . COLLEMBOLA (springtails)
2B "Spring" absent 3

3A Antennae absent . . . . PROTURA (proturans)
3B Antennae present 4

4A Antennae shorter than, or about as long as, head 5
4B Antennae clearly longer than head 7

5A Body compressed; antennae about as long as head . . . . SIPHONAPTERA (fleas)
5B Body not compressed; antennae much shorter than head 6

6A Piercing and sucking mouthparts . . . . ANOPLURA (sucking lice)
6B Biting mouthparts . . . . MALLOPHAGA (biting lice)

7A Abdomen with tubular, pincher-like or threadlike extension behind 8
7B Abdomen without extensions behind 11

8A Abdomen with a pair of short tubes; piercing mouthparts held under head . . . . HOMOPTERA (aphids)
8B Abdomen without tubes; mouthparts for biting and chewing 9

9A Abdomen with three filamentous appendages as long as body; body covered with scales . . . . THYSANDURA (silverfishes- firebrats)
9B Abdomen with pincher-like structures or no more than two filamentous appendages; body not covered with scales 10

10A Eyes absent . . . . ENTOTROPHI
10A Eyes present and conspicuous . . . . DERMAPTERA (earwigs)

11A Mouthparts tubular, for sucking 12
11B Mouthparts not tubular, for biting and chewing 14

12A Body covered with scales; mouth in form of a coiled tube . . . . LEPIDOPTERA (moths, butterflies)
12B Body not covered with scales; mouth in form of a straight tube . . . 13

13A Sucktube long, straight and beak-like; body flattened from top to bottom; tips of feet with claws . . HEMIPTERA (true bugs)

13B Sucking tube short and conical; body not flattened from top to bottom; tips of feet with pads; wings narrow, hairy and without veins . . . . THYSANOPTERA (thrips)

14A Antennae and legs long and slender . . . . .ORTHOPTERA (grasshoppers, cockroaches)

14B Antennae not unusually long and slender 15

15A Body noticeably constricted at base of abdomen; antennae elbowed . . . . HYMENOPTERA (bees, wasps, ants)

15B Body not constricted at base of abdomen; antennae not elbowed . . . . ISOPTERA (termites)

16A One pair of wings . . . . DIPTERA (true flies)

16B Two pairs of wings 17

17A Front and hind wings similar in texture 18

17B Front and hind wings not alike in texture 27

18A Wings long and narrow, without veins, with a fringe of fine hair; tips of feet with pads . . . . THYSANOPTERA (thrips)

18B Wings without fringe of fine hair; tips of feet with claws 19

19A Wings and body covered with scales; mouthparts in form of a coiled sucking tube . . . . . LEPIDOPTERA (moths and butterflies)

19B Wings and body not covered with scales; mouthparts not in form of a coiled tube 20

20A Front wings distinctly narrower than hind wings; abdomen may have two short, prominent filaments . . . . PLECOPTERA (stoneflies)

20B Front wings larger than, the same size as, or only slightly narrower than hind wings; filaments usually absent (if present, front wings are much larger than hind wings) 21

21A Front wings and hind wings similar size and shape, or front wings much larger 22

21B Front wings longer and wider than hind wings 25

22A Wings with a few longitudinal veins but no crossveins; body usually two to four mm in length . . . . ISOPTERA (termites)

22B Wings with crossveins; body usually more than four mm long 23

23A Wings with many crossveins and longitudinal veins, forming a network; front wings may be slightly narrower than hind wings; eyes very large (at least half of head area) . . . . .ODONATA (dragonflies, damselflies)

23B Wings with veins not forming a network; front wings about same size as hind wings; eyes small (less than half of head area) 24

24A Wings much longer than body, smooth, with numerous crossveins, and held at rooflike angle over body when at rest . . . . NEUROPTERA (lacewings, ant-lions, dobsonflies)

24B Wings not much longer than body, smooth, with hairs or patches of scales, many longitudinal veins but few crossveins, and held flat on back when at rest . . . . TRICHOPTERA (caddisflies)

25A Abdomen with two or three filaments longer than body; hind wings about one-third the size of front wings. EPHEMEROPTERA (mayflies)

25B Abdomen without filaments; hind wings at least half as large as front wings 26

26 A Wings held at a rooflike angle over body when at rest; mouthparts absent or form a jointed sucking tube . . . . .HOMOPTERA (aphids, cicadas, leafhoppers)

26B Wings held flat on back when at rest; mouthparts for biting chewing, lapping or sucking; abdomen often has a stinger . . . . .HYMENOPTERA (bees, wasps, ants)

27A Front wings leathery at base, membranous at tip; mouthparts in form of long sucking tube . . . HETEROPTERA (land-bugs, water-bugs)

27B Front wings leathery or parchment-like throughout; mouthparts for biting or chewing 28

28A Abdomen with two pincher-like extensions behind; wings short, not covering all of abdomen . . . . . .DERMAPTERA (earwigs)

28B Abdomen without pincher-like extensions behind; wings usually cover all of abdomen 29

29A Front wings with veins, long, narrow, and parchment-like; hind wings broad, often fan-shaped . . . . ORTHOPTERA (grasshoppers, cockroaches)

29B Front wings veinless, usually not parchment-like (if long and narrow, hind wings also long and narrow) 30

30A Front wings and hind wings broad; front wings meet in centre of back forming hard, veinless cover for hind . . . . COLEOPTERA (beetles)

30B Front wings and hind wings long and narrow; front wings do not form hard cover for hind wings; tip of abdomen may be curved forward over back . . . . MECOPTERA (scorpionflies)

Adapted from BSCS Green Version Student's Manual (1963)

KEY TO THE FAMILIES OF ALBERTA FISHES (Morley Riske)

1A Mouth without true jaws, instead a suctorial disc; no paired fins . . . . .PETROMYZONTIDAE (lampreys)
1B Mouth with true jaws; paired fins; gill covers present 2

2A Heterocercal caudal fin; five rows of bony plates; mouth ventral . . . . ACIPENSERIDAE (sturgeons)
2B Homocercal caudal fin; body covering of overlapping scales or naked 3

3A Body scaleless; prominent whisker-like barbels . . . . .ICTALURIDAE (catfishes)
3B Body scales 4

4A Pelvic fins abdominal; one dorsal fin 5
4B Pelvic fins thoracic; two dorsal fins or one preceded by free spines 12

5A Adipose fin present 6
5B Adipose fin absent 9

6A Scales weakly ctenoid; spines in dorsal fin . . . . PERCOPSIDAE (troutperches)
6B Scales cycloid; no spines in dorsal fin 7

7A Scales small, more than 100 in lateral line; teeth large . . . . SALMONIDAE (salmons, trouts)
7B Scales larger, fewer than 100 in lateral line; teeth weak or absent 8

8A Dorsal fin base shorter than head . . COREGONIDAE (whitefishes)
8B Dorsal fin base longer than head . . . THYMALLIDAE (graylings)

9A Gill slits extended far forward below; gill membranes free from isthmus; teeth present in mouth 10
9B Gill slits not extended far forward below; gill membranes attached to isthmus; teeth absent from mouth 11

10A Scales developed on head; snout broad and flat . . ESOCIDAE (pikes)
10B No scales on head; snout short and blunt . . HIODONTIDAE (mooneyes)

11A Lips thick with papillae; mouth fitted for sucking, distinctly inferior . . . . .CATOSTOMIDAE (suckers)
11B Lips thick; mouth not fitted for sucking . . . . CYPRINIDAE (minnows)

12A One dorsal fin preceded by free spines . . . . GASTEROSTEIDAE (sticklebacks)
12B Two dorsal fins 13

13A Scales ctenoid 14
13B Scales cycloid, small, dorsal fin without spines; chin with median barbel . . . . GADIDAE (cods)

14A First dorsal fin spiny . . . . .PERCIDAE (perches)
14B Body scaleless or with prickles only . . . . .COTTIDAE (sculpins)

KEY TO THE FISHES OF ALBERTA (University of Alberta and Sources)

FAMILY PETROMYZONTIDAE

Seven pore-like openings along each side of the body immediately behind the head . . . . Entosphenus Japonicus (ARCTIC LAMPREY)

FAMILY ACIPENSERIDAE

Toothless ventral mouth preceded by four tactile barbels; skeleton cartilaginous . . . . Acipenser fulvescens (LAKE STURGEON)

FAMILY ICTALURIDAE

Eight barbels about mouth; adipose fin present; strong sharp spine at front of dorsal and each pectoral fin . . . . .Noturus Flavus (STONE CAT)

FAMILY PERCOPSIDAE

One or two spines in dorsal and anal fin; adipse fin present . . . . Percopsis omiscomaycus (TROUTPERCH)

FAMILY SALMONIDAE

1A Spots pale or reddish on a dark background; lower fins with a white leading edge; teeth absent on shaft of vomer 2
1B Black spots on body; teeth present on shaft of vomer 4

2A Caudal fin nearly square; dark green wavy markings on dorsal and caudal fins; sides with reddish spots with blue borders . . . . .Salvelinus fontinalis (BROOK TROUT)
2B Caudal fin forked; dorsal and caudal fins plain or light spotting; sides with light or pinkish spots 3

3A Caudal fin deeply forked; dorsal and caudal fins, head and body with irregular light spots; more than 90 pyloric caeca . . . . .Salvelinus namaycush (LAKE TROUT)
3B Caudal fin shallowly forked; back uniform with round yellow or pink spots . . . . Salvelinus malma (DOLLY VARDEN)

4A Large black spots on body, many surrounded by pale halos; ground color golden brown; caudal fin almost square . . . . SALMO TRUTTA (BROWN TROUT)
4B No halo around black spots ; dorsal surface dark olive to black. 5

5A Hyoid teeth present; no whitish edge to fins; red dash below lower jaw . . . . Salmo clarkii (CUTTHROAT TROUT)
5B Hyoid teeth absent; whitish edge to dorsal, anal, and pelvic fins; no red dash below jaw. Salmo gairdnerii (RAINBOW TROUT)

FAMILY COREGONIDAE

1A Mouth large with teeth very weak or absent; tip of lower jaw projects beyond upper; body elongate and compressed . . . . Stenodus leucichthys (INCONNU)*
1B Mouth relatively small with toothless jaws 2

2A Single flap between nostrils; short gill rakers; young with parr marks; anal rays usually eight to twelve 3
2B Two flaps between nostrils; gill rakers long and slender; young without parr marks; anal rays usually thirteen or more 4

3A Adipose fin very large, base more than 1.5 times eye diameter; snout pointed; scales in 74 or 90 rows . . . . Prosopium williamsoni (MOUNTAIN WHITEFISH)
3B Adipose fin small, base less than 1.5 times eye diameter; scales in 59 to 70 rows; length usually less than six inches . . . . Prosopium coulteri (PYGMY WHITEFISH)*

4A Body deep and compressed; gill rakers less than 33; vertical upper lip . . . . Coregonus clupeaformis (LAKE WHITEFISH)
4B Body trout-like; gill rakers more than 38; mouth terminal; lower jaw projects slightly beyond upper . . . . Coregonus artedii (SHALLOWATER CISCO)

FAMILY THYMALLIDAE

Dorsal fin long and high, with green and rose spots, and edged in red . . . . . . Thymallus arcticus (ARCTIC GRAYLING)

FAMILY ESOCIDAE

Long slender body; dorsal fin posteriorly located; well toothed; elongated jaws . . . . Esox lucius (NORTHERN PIKE)

FAMILY HIODONTIDAE

Deep, compressed body with large silvery scales; eyes large; mouth small with well developed teeth which are also present on tongue . . . . Hiodon alosoides (GOLDEYE)

FAMILY CATOSTOMIDAE

1A Anterior rays of dorsal fin twice the length of the rest . . . . Carpoides cyprinus (QUILLBACK CARPSUCKER)
1B Anterior rays of dorsal fin not twice the length of the rest . . 2

2A Scales in more than 50 rows; air bladder of two chambers 3
2B Scales in fewer than 50 rows; air bladder of three chambers . . . . Moxostoma macrolepidotum (NORTHERN REDHORSE)

3A Upper and lower lips separated by a distinct notch at corners of mouth; posterior division of air bladder slender . . . . Pantosteus jordani (NORTHERN MOUNTAIN SUCKER)
3B Upper and lower lips not separated by a notch; posterior division of air bladder broad 4

4A Scales small, 90 to 115 in lateral line . . . . Catostomus catostomus (LONGNOSE SUCKER)
4B Scales large, 60 to 80 in lateral line 5

5A Dorsal fin rays, 10 to 12 . Catostomus commersoni (WHITE SUCKER)
5B Dorsal fin rays, 13 to 15 . . . . Catostomus macrocheilus (LARGESCALE SUCKER)

FAMILY CYRPINIDAE

1A Dorsal fin base long; dorsal and anal fins each with a strong spine 2
1B Dorsal fin base short; no spines in fins 3

2A Upper jaw with two fleshy barbels on each side; scales in lateral line usually more than 32. .Cyprinus carpio (CARP)*
2B Barbels absent; lateral line scales fewer than 32 . . . . Carassius auratus (GOLDFISH)*

3A Premaxillaries not protractile; snout long, projecting far beyond mouth . . . . Rhinichthys cataractae (LONGNOSE DACE)
3B Premaxillaries protractile; snout not long and overhanging . . . 4

4A Maxillary with a barbel 5
4B Maxillary without a barbel 6

5A Pectoral fins long and sickle-shaped; head wide and flattened . . . . Hybopsis gracilis (FLATHEAD CHUB)
5B Pectoral fins rounded; head not wide and flattened . . . . Hybopsis plumbea (LAKE CHUB)

6A Anal fin base distinctly longer than dorsal base; dorsal fin far behind pelvics. . Richardsonius balteatus (REDSIDE SHINER)
6B Anal fin base about same length as dorsal base; dorsal fin not far behind pelvics 7

7A Head long and pointed; mouth large, maxillary reaching to below eye . . . . Ptychocheilus oregonense (NORTHERN SQUAWFISH)
7B Head short; mouth not large, maxillary not reaching to below eye 8

8A Lateral line scales more than 60 9
8B Lateral line scales fewer than 55 10

9A Two parallel lateral bands; lower lip projecting beyond the upper and snout . . . . Chrosomus eos (REDBELLY DACE)
9B Usually one faint dark lateral band; projecting upper lip . . . . Semotilus margarita (NORTHERN PEARL DACE)

10A First dorsal ray separated by a membrane from first well-developed ray; tubercles on snout of breeding males . . . . Pimephales promelas (FATHEAD MINNOW)
10B First dorsal ray closely attached to first well-developed ray . . . 11

11A Anal fin rays, 9 to 12 . . Notropis atherinoides (EMERALD SHINER)
11B Anal fin rays, 7 or 8, rarely 9 12

12A Black spot at base of caudal fin . . . . Notropis hudsonius (SPOTTAIL SHINER)
12B No black spot on caudal base; lateral band present 13

13A Lateral band continued forward through eye and onto muzzle . . . . Notropis heterolepis (BLACKNOSE SHINER)
13B Lateral band not so . . . . Notropis blennius (RIVER SHINER)

FAMILY GASTEROSTEIDAE

1A Dorsal spines, 5 to 7 . . . Culaea inconstans (BROOK STICKLEBACK)
1B Dorsal spines, 9 usually . . . . Pungitius pungitius (NINESPINE STICKLEBACK)

FAMILY GADIDAE

Body long, caudal portion laterally compressed; elongate dorsal and anal fins; single barbel at tip of chin. Lota lota (BURBOT)

FAMILY PERCIDAE

1A Preopercular bone serrate; mouth large; branchiostegals seven . . . 2
1B Preopercular bone smooth; mouth small; branchiostegals six; small fishes, usually one to four inches long 4

2A Body deep, compressed, and with definite crossbars; pelvic fins inserted close together; no canine teeth . . . . Perca flavescens (YELLOW PERCH)
2B Body elongate, almost cylindrical in section; without crossbars; pelvic fins widely separated; prominent canine teeth 3

3A Dorsal fins with rows of black spots; end of first dorsal fin without prominent black blotch. Stizostedion canadense (SAUGER)
3B Dorsal fins with obscure mottlings; end of first dorsal fin with a large black blotch . . Stizostedion vitreum (YELLOW WALLEYE)

4A Premaxillaries protractile; body almost round in section . . . . Etheostoma nigrum (JOHNNY DARTER)
4B Premaxillaries nonprotractile; body compressed . . . . Etheostoma exile (IOWA DARTER)

FAMILY COTTIDAE

1A Gill membranes free from isthmus; dorsal fins widely separated
. . . . *Myxocephalus quadricornis* (DEEPWATER SCULPIN)
1B Gill membranes attaced to isthmus; dorsal fins scarcely separated 2

2A Two pores on tip of chin; preopercular spine short and little curved; body smooth . . . *Cottus cognatus* (SLIMY SCUPLIN)
2B One pore on tip of chin, body prickling variable 3

3A Mouth large; anal rays 15 to 19; large sharp preopercular spine; prominent black spot at posterior of first dorsal . . . . . .
. . . . *Cottus asper* (PRICKLY SCULPIN)
3B Mouth small; anal fins 11 to 16; very wide, flat head with preopercular spine conspicuously curved upward and inward; usually very dense prickles *Cottus ricei* (SPOONHEAD SCULPIN)